NASA Tech Briefs

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December 1992 Vol 16 No. 12

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TECHNOLOGY 2002

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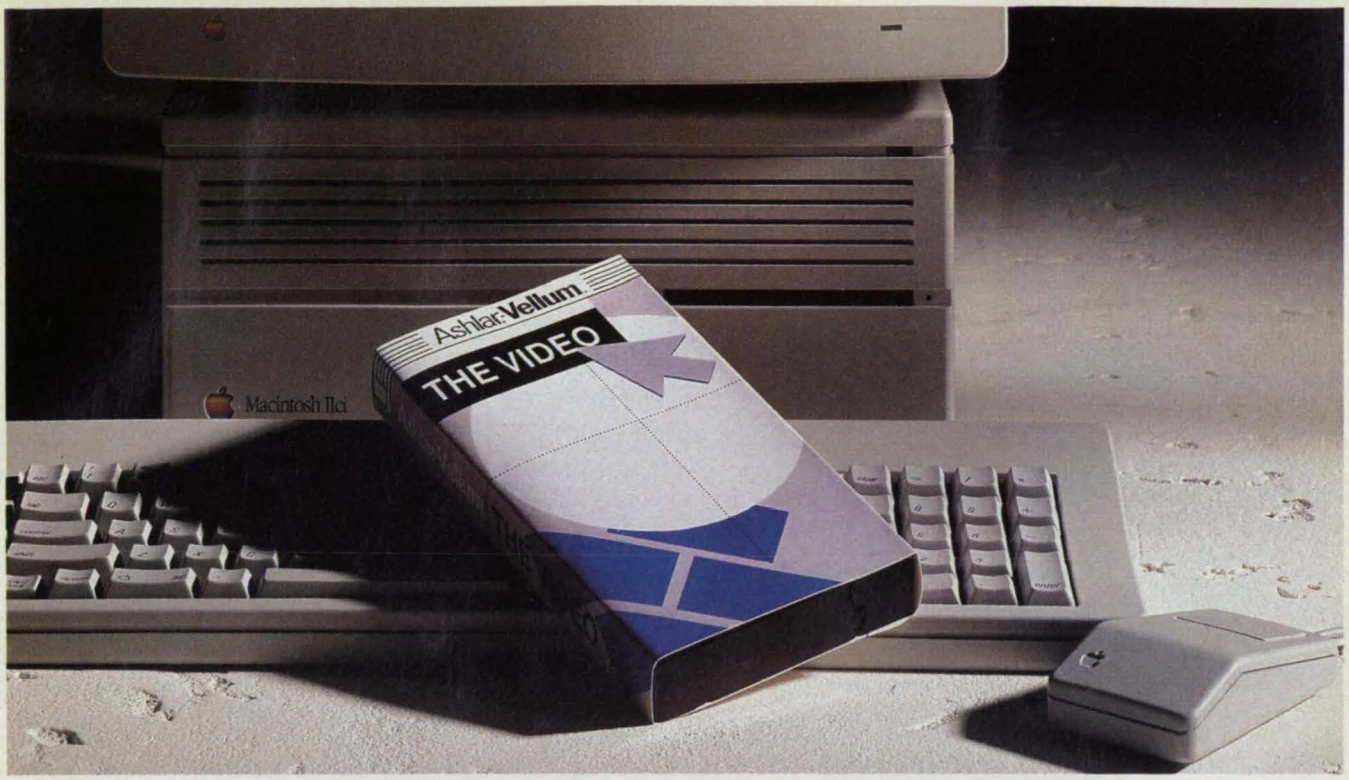

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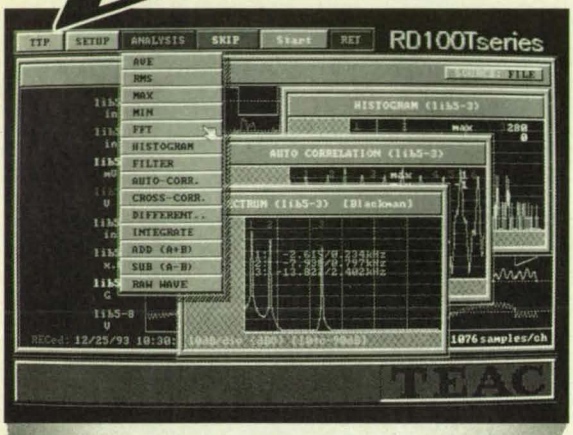

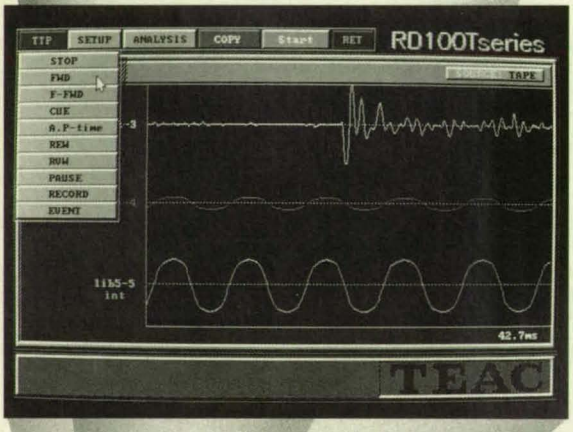

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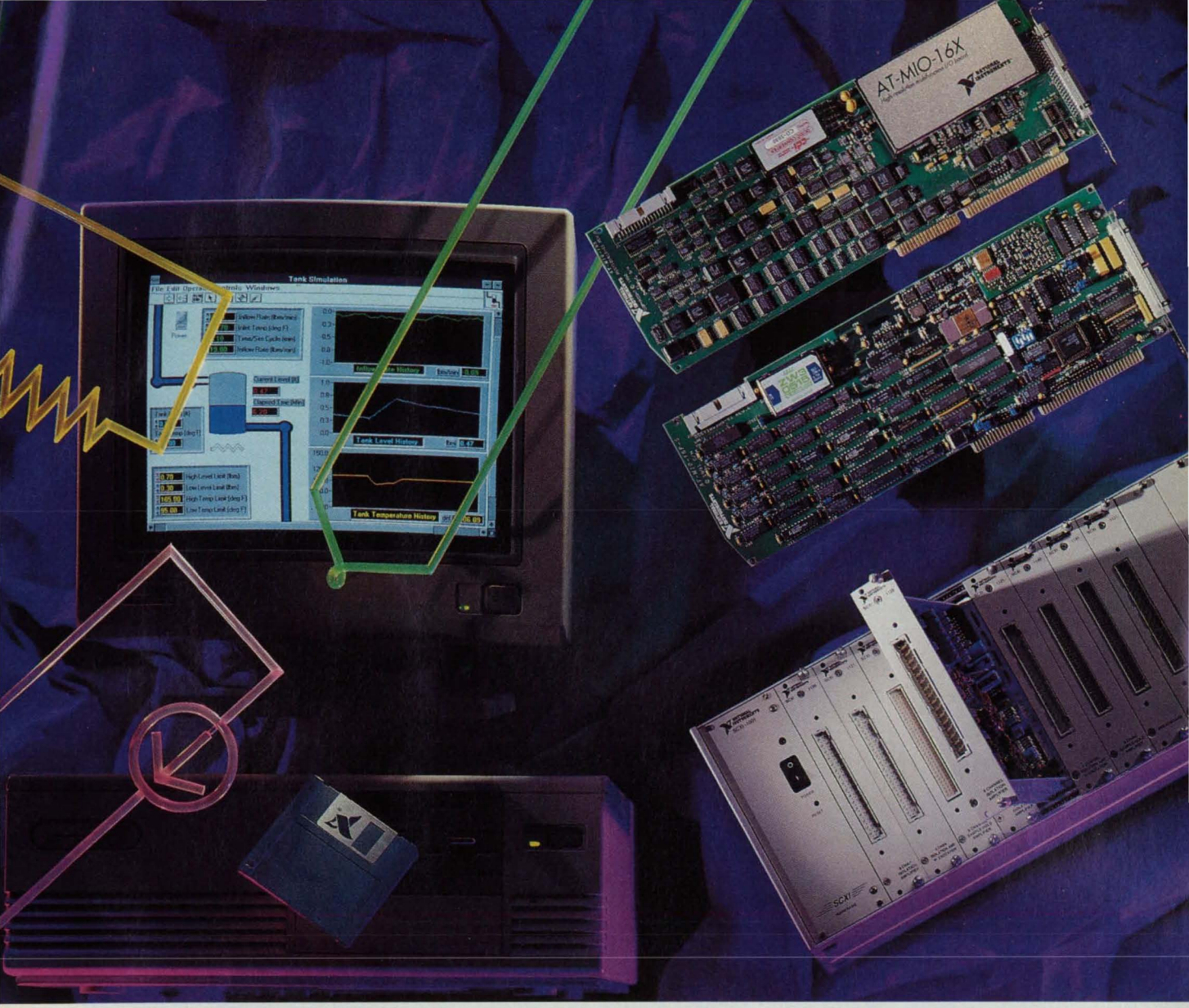

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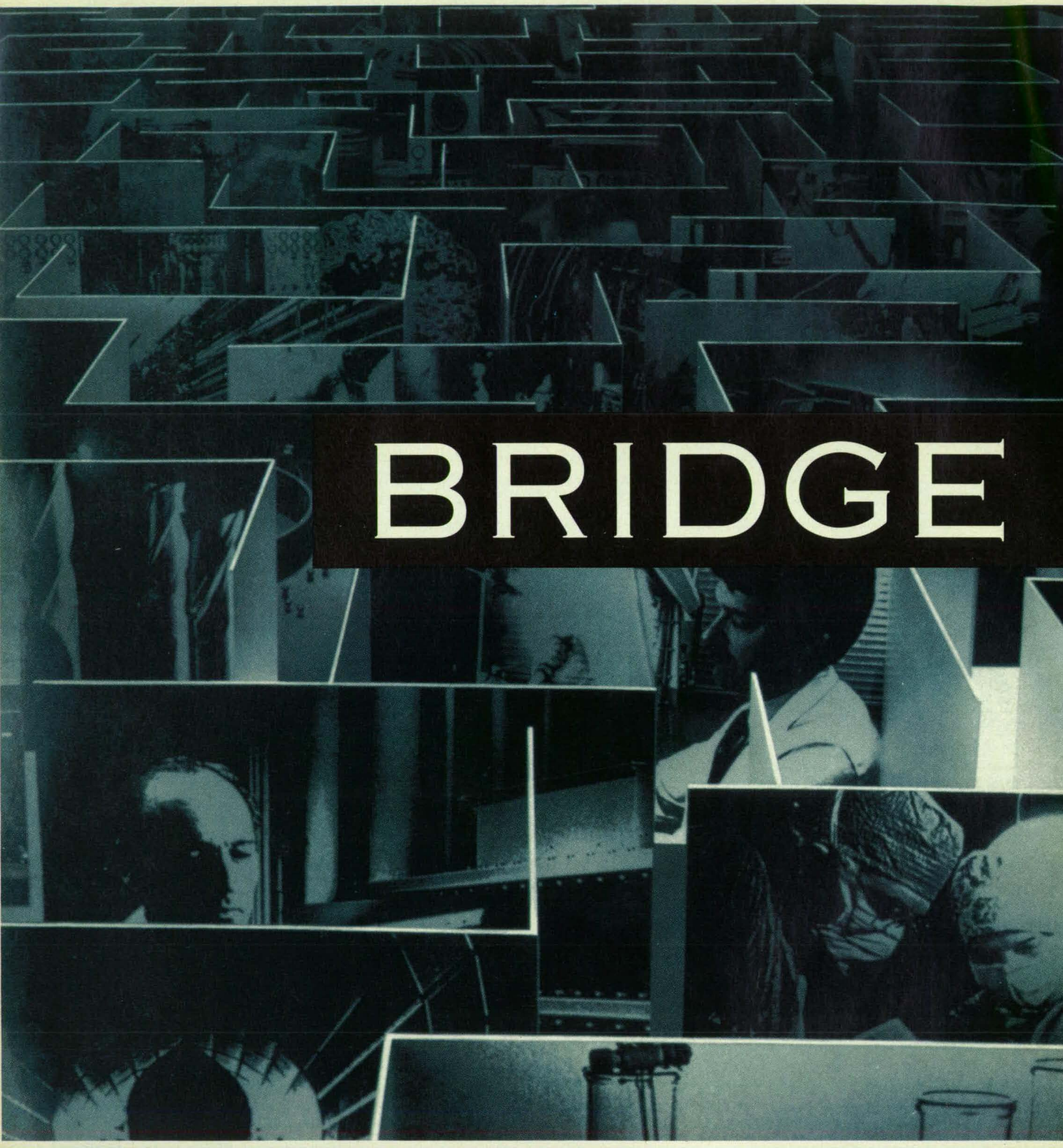

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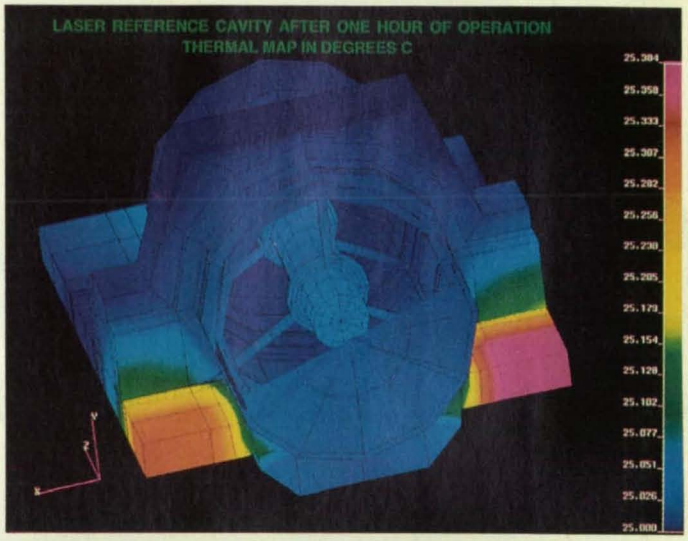

Photo courtesy NASA Langley

Engineers at NASA's Langley Research Center are using advanced software to animate the thermal response of a system as an active color map—a highly effective visual indication of heat flow. The technique has applications in plastics manufacturing, automobile engine design, analysis of chemical reactions, and other fields where the understanding of thermal flow is critical. ***See page 14.***

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(Continued on page 8)

THE ONLY TAPE DRIVE THAT PUTS 25GB ON A SINGLE 8MM TAPE.

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The state-of-the-art liquid crystal display gives you complete drive status information. Command under execution, transfer rate, tape remaining, and ECC are presented in a clear easy-to-read format. By offering such features as data compression – for five times the storage capacity per tape – and data encryption – giving you data access control – the CY-8500 adapts to your company's growing needs. We'll adapt to your site requirements too, with rack mounting options and cable lengths of up to 80 feet.

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Contents *(continued)*

Photo courtesy Jet Propulsion Lab

The Data Egg, a single-handed text entry unit invented at Jet Propulsion Laboratory, promises to make computers truly portable and allow access to those normally barred from using them, such as the handicapped. Here, a bedridden patient uses the device to type in text while viewing a virtual image of the PC screen projected a few feet in front of his eyes. Turn to NASA's Innovators, page 14.

ABP BPA

DEPARTMENTS

on the cover:

NASA's leading scientists and engineers will present an array of licensable inventions at the Technology 2002 national tech transfer conference (see NASA's Innovators, page 14). They will be joined by technologists from eleven other government agencies and their contractors, all showcasing new technologies in areas identified by the White House as critical to America's long-term economic health: high-performance computing and communications, microelectronics, manufacturing, advanced materials, biotechnology, and energy/environmental technologies.

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Efforts to monitor and manage the earth's resources will be improved by a new satellite sensor system, the Enhanced Thematic Mapper (ETM). Built by Hughes Aircraft Company and scheduled for launch aboard the Landsat 6 satellite, the ETM will collect important scientific and commercial data on agriculture, forests, water and mineral resources, and land use. The earlier thematic mapper, predecessor of the new instrument, provided imagery and data on the oil spill in the Persian Gulf, and monitored the oil well fires in Kuwait to expedite fire-fighting efforts. The ETM includes a 32-channel panchromatic band with 15-meter resolution, and redundant subassemblies and circuits for extended life in space.

A new electronics manufacturing process not only saves time and money, but will help save our environment. This process, developed by Hughes, uses a new water-soluble flux called HF1189 in soldering circuit card assemblies. This eliminates the need for ozone-damaging chlorofluorocarbons (CFCs), which are used to clean conventional rosin-based fluxes. With HF1189's rapid and complete deoxidizing action, electronic card assemblies can be soldered and cleaned in about one-half the time needed for rosin-based fluxes. Hughes estimates that by converting its wave soldering machines to this new process, it will save operating costs of several million dollars annually.

In the first full-scale "disaster drill" simulating a failed satellite transponder, Hughes satellite and network controllers restored a Disney feed placed on Galaxy II, transponder 4, after customer Upsouth Atlanta had intentionally dropped the feed as part of the drill. The object was to test satellite operating instructions and staff response, to see if any deficiencies existed. There was no disruption of programming to Upsouth Atlanta, as Hughes immediately coordinated with the Galaxy Program Office and moved the Upsouth feed to another Galaxy transponder. Restoring service to the primary transponder was completed in two minutes.

Hughes is helping solve industrial hydrocarbon contamination of soil and groundwater with a state-of-the-art steam injection process that removes and treats hydrocarbons without excavating the soil. First, steam is injected into the ground. At the right temperature and pressure, it forces the hydrocarbons to migrate to extraction wells. Once stripped from the soil, these hydrocarbon vapors and liquids are safely extracted for treatment. This in-place method of hydrocarbon removal has definite advantages. Being nonobtrusive, it does not require a plant to shut down, which accelerates cleanup and reduces costs. This remediation process is one of many examples in which Hughes is using existing technology to solve environmental problems.

Combining one of the largest VSAT networks in the United States with long-term satellite capacity, Wal-Mart will continue to expand its video and data communications network. Hughes' very small aperture terminals (VSATs) and SBS Ku-band satellite are making it possible for Wal-Mart to connect its central Arkansas headquarters with more than 1,800 retail stores and regional warehouses across the country.

For more information write to: P.O. Box 80032, Los Angeles, CA 90080-0032

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Subsidiary of GM Hughes Electronics

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NASA PATENTS

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

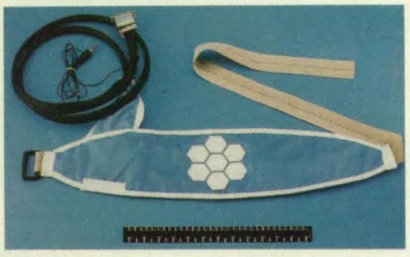
Passive Fetal Monitoring System

(US Patent No. 5,140,992)

Inventors: **Allen J. Zuckerwar**, **Earl T. Hall**, **Donald A. Baker**, and **Timothy D. Bryant**, Langley Research Center

An innovative sensor permits an expectant mother to wear a fetal monitor during daily activities. The monitoring system incorporates piezoelectric polymer film combined with a metallic mounting plate fastened to a belt. Shielded cable attaches a signal processing unit to the system. The sensor receives pressure pulses emitted by the fetal heart while filtering out pulses from other sources, such as the mother's heart.

For More Information Circle No. 805



Laser Velocimeter for Near-Surface Measurements

(US Patent No. 5,090,801)

Inventor: **Dennis A. Johnson**, Ames Research Center

Mr. Johnson has designed a miniature laser Doppler velocimeter that can measure near-wall, three-dimensional turbulence in a wind tunnel or similar flow environment. The instrument includes at least one beam-turning device with a mirror or prism at one end. It receives and reflects laser light and then redirects it at various angles to obtain measurements for all three velocity components at grazing incident angles.

For More Information Circle No. 807

Stable-Stream-Producing, Flexible Orifice Independent of Fluid Pressure

(US Patent 5,080,286)

Inventor: **Andrew D. Morrison**, Jet Propulsion Laboratory

In conventional liquid-projecting hoses, such as those used by firefighters, the exiting stream disperses near to the nozzle. Mr. Morrison has designed a flexible membrane for the nozzle opening that compensates for varying fluid pressure and flow rates to extend the coherent fluid stream. Incorporating at least two flow channels, the membrane deforms with pressure changes to redirect the fluid streams from the channels for a stable, unified stream.

For More Information Circle No. 802

Real-time, Pre-detection Dynamic Range Compression

(US Patent No. 5,130,530)

Inventor: **Hua-Kuang Liu**, Jet Propulsion Laboratory

Optical signal processing techniques must handle a wide dynamic range of signals, some of which require pre-detection compression to prevent information loss. Applicable in the spectral regions of visible signals, Mr. Liu's method permits real-time, pre-detection, tunable dynamic range compression by applying an optical signal to a photorefractive crystal and then applying a portion of the crystal output to a receiver.

For More Information Circle No. 801

Acoustophoresis Method and Apparatus

(US Patent No. 5,147,562)

Inventor: **Joseph S. Heyman**, Langley Research Center

Acoustophoresis provides a separation technique that differentiates chemical species by their acoustic absorption, scattering, and radiation properties. It employs an ultrasonic transducer emitting an acoustic wave to one end of a sample container holding at least two species with differing acoustic absorption coefficients. The wave frequency is tuned to the point of resonance for the species to be separated and drives it to the opposite end of the container for removal.

For More Information Circle No. 806

Boron-Carbon-Silicon Polymers and Ceramic and a Process for the Production Thereof

(US Patent 5,130,278)

Inventors: **Salvatore Riccitiello**, **Ming-Ta Hsu**, and **Timothy S. Chen**, Ames Research Center

Combining silicon, boron, and carbon results in a polymer and ceramic with enhanced properties. The ceramic can be used to infiltrate other ceramic structures, producing a composite with improved temperature and oxidation resistance. The organic preceramic polymer can be decomposed in a closed system to deposit particles on a substrate, or shaped and then pyrolyzed to produce the ceramic in article form.

For More Information Circle No. 803

Sharps Container

(US Patent No. 5,145,063)

Inventor: **Angelene M. Lee**, Johnson Space Center

Ms. Lee has designed a small-volume, reusable container for disposing of "sharps," which include items such as hypodermic needles and broken glass vials. Constructed from lightweight, nonmagnetic metal, the cup component is tapered and taller than it is wide. Sharps pass through an opening in the lid that has a spring-biased closure flap and, if metallic, are retained by a magnet at the bottom of the cup.

For More Information Circle No. 804

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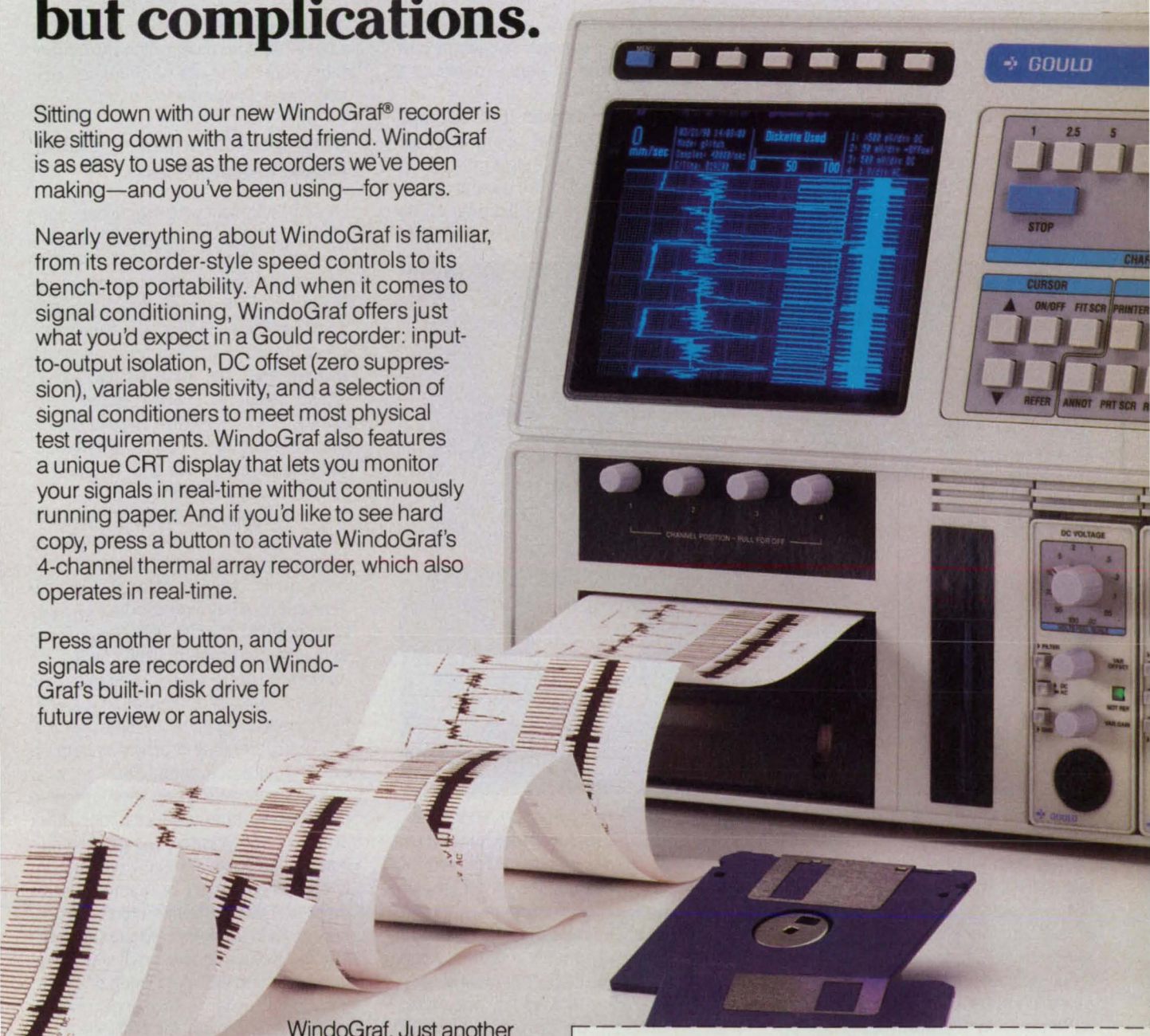

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NASA's INNOVATORS

Technology 2002, the third national technology transfer conference and exposition (December 1-3, Baltimore convention center) will feature presentations by over 50 of NASA's leading researchers detailing a broad array of space-based inventions with down-to-Earth applications. In the second of two parts, we highlight some of their cutting-edge work.

Concurrent Engineering Tools For Tomorrow

The successful integration of design, thermal, structural, and optical analysis techniques by engineers at the Langley Research Center has streamlined aerospace engineering tasks and could benefit a wide range of industries looking to improve quality and efficiency through concurrent engineering.

A color thermal map illustrates heat flow in the lunar rover.

To begin, interfaces are needed to join the software programs used for the respective design and analysis processes. Langley engineers developed an interface for Pro-Engineer® CAD software and PATRAN 2.5 solid modeling software. Making an analytical model directly from design geometry eliminates inefficient and inaccurate transfers of the model to paper and facilitates design changes. The technique could aid in the mass-production of automobile parts, machine equipment, and plastic components.

"It saves a lot of time because you are not duplicating efforts between designers and analysts—manual input is done only once," said Ruth Amundsen, a Langley aerospace engineer. "Also, the answers you derive are more reliable because the actual part is analyzed rather than a designer's approximation."

In another project, the Langley team determined that using a single integrated model for both thermal and structural analysis of an optical bench enables accurate predictions of its performance. Translating a PATRAN model directly to SINDA-85 for thermal analysis allows exact calculation of thermally-driven deflection in combination with various structural loading conditions. The data then can be used to automatically modify a CODE-V optical analysis model. This makes optimization easier and could, according to Amundsen, be applied wherever close tolerances between optical components must be maintained, such as on automated fabrication and assembly lines that use lasers for experimentation and measurement.

Further, the team combined analysis and presentation by using the PATRAN model to generate an animated color map of thermal response over time. Such visualization of heat flow could benefit plastics modeling and extrusion processes, automobile engine design, electronics design and fabrication, analysis of chemical reactions, and power plant design.

Intelligent Instrument Yields Real-Time Results

Any scientist who has spent long nights nursing an experiment along can attest to the amount of attention laboratory instruments require. Automating them, however appealing, presents multiple challenges. An instrument conducting real-time chemical sample analysis, for example, ideally would recognize unexpected variances, offer alternative hypotheses to explain such variances, and then suggest ways to modify the analysis to confirm its hypotheses.

Artificial intelligence researchers and planetary microbial ecologists at Ames Research Center have collaborated on software for such a uniquely capable instrument. Their first product couples a differential thermal analyzer (DTA) and a gas chromatograph (GC). The automated geochemistry and microbial analysis tool performs real-time identification of organic and mineralogical soil constituents and provides data on soil structure and chemistry.

Originally developed for moon use, the new instrument offers a laboratory and field analysis tool for rapid identification of solid samples without refined wet-chemistry or scanning calorimetry. It can be applied to soil analysis in toxic and hazardous environments, DNA synthesis, analysis of crystal purity, and GC monitoring of closed life support systems. Now under consideration is a project for NASA's Earth Observing System in which the instrument would calibrate sensors used for soil analysis in global change research.

Although the DTA-GC instrument is somewhat specialized, the control technology is not. "It could be used in any laboratory where the researcher is seeking reactive, predictive control with data analysis," said Thompson, who is eager to collaborate with industry in adapting the software to other

instruments. The Ames researchers next plan to port it to a bioreactor. According to Thompson, it works best at the raw data level and, once generalized, could assist in critical control and analysis decisions and enable instrument operation and analysis under remote or hostile conditions.

The Dynamic Data Egg

An electronic device developed at the Jet Propulsion Laboratory (JPL) enables single-handed data entry while walking, running, driving, riding a bicycle, reclining on a sofa, or even floating in space. Dubbed the Data Egg, the convenient interface can be used autonomously in virtually any environment or tethered to a computer to serve as an auxiliary keyboard.

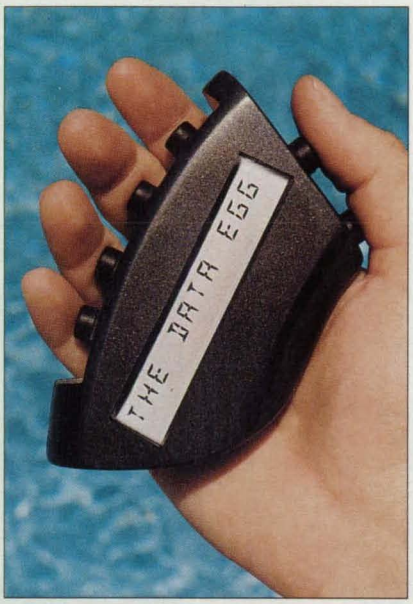
Invented by JPL's Gary Friedman in 1990, the first prototype was shaped like an egg to make it both easy to hold and highly portable. Subsequent versions have assumed a variety of shapes and sizes, incorporating such features as LCDs and finger grips or belt clips to eliminate the need for a hand strap.

"I remember as a journalist years ago wishing for a way to take notes during a bumpy bus ride—this is it," said Friedman. Unlike a tape recorder, the Data Egg requires no transcription to generate a paper copy—input can be downloaded to a computer and printed. Moreover, the device operates discreetly and quietly.

Data is entered by pressing combinations of seven buttons positioned where the fingers, or in some models the finger joints, naturally fall when clasping the unit. The seven-button alphabet was invented in England several years ago to address the problem of tiny, unusable keyboards on pocket electronic devices. It can be learned in as little as an hour, according to Friedman. "Although it's not as fast as typing with two hands," he said, "I now can enter about 30 words per minute." The buttons also permit numerical functions, punctuation, and a cursor as well as all control, alt, and function keys.

Eliminating the desk and chair extends computer access to those for whom traditional operating postures are impossible. A new workstation, designed for multiple sclerosis sufferers and others who may be bedridden, couples the Data Egg with a head-mounted virtual display device. Software written by Friedman converts signals from the handheld device to keyboard characters for direct data entry while a virtual image of the PC's screen hovers approximately five feet in front of the user. Friedman is investigating ways to incorporate a built-in text-to-speech converter or even more complex speech synthesizers.

He envisions models compatible with PCs and Macintosh computers that will include software to help organize notes. "A simple commercial model



could be made for $20, then enhanced with additional memory and special features for specific tasks," he said. A second-generation model currently in development will function as a phonebook and autodialer.

An Environmentally-Safe Refrigerant

In February 1992, the federal government shifted the deadline for eliminating ozone-depleting chlorofluorocarbon refrigerants (CFCs) from the year 2000 to 1996. Unfortunately for manufacturers of refrigerators and air conditioners, it could not similarly curtail the time and expense required to find adequate substitutes.

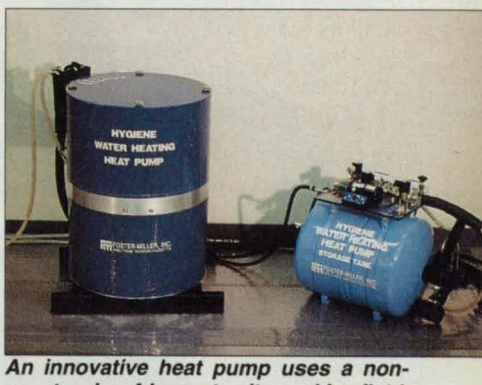
Many of the known alternatives are less efficient than CFCs, which were favored for their stability. One promising strategy advanced by engineers at Foster-Miller Inc., working under a Small Business Innovation Research contract from Marshall Space Flight Center, employs optimized combinations of the known non-CFC refrigerants. The project team recently built an efficient heat pump that uses a nonazeotropic refrigerant mixture (NARM) as its working fluid.

A NARM is made up of two or more refrigerants of different volatilities and, unlike commonly used freons, does not act as a pure fluid. A NARM changes composition as it boils or condenses, resulting in a temperature variation during a constant-pressure phase-change. This difference can reduce heat pump irreversibilities, such as the pressure ratio and the temperature difference between the working fluid and the material it is heating or cooling.

Their potential to not only maintain but in some cases improve a system's heat transfer efficiency makes NARMs appealing. A system's coefficient of performance (COP) is calculated by dividing the degree of cooling achieved by the amount of energy required. For example, the COP of an air conditioner would be the net cooling in watts divided by the compressor power utilized in watts. Experiments conducted at Marshall with prototype heat pumps not optimized for either fluid demonstrated a 30% increase in COP for the NARM over R-12 freon. "With an optimized system the increase would be even greater," said Marshall engineer Doug Westra, the project monitor.

Despite its potential, the approach has various shortcomings that will require attention. Without a means to monitor the relative concentrations of mixture components, any leak means draining the entire system and starting over. Since the compounds have different densities, they will leak at different paces. Also problematic is the narrow load range and the need for a relatively large heat exchanger. Because of its size and weight, the latter presents a liability for space use.

Westra expects, nevertheless, that increased development for terrestrial applications will prove the technology's merit and eventually lead to use in orbit. "These mixtures show enough promise to warrant further development," said Westra. "With serious efforts, commercial systems could be available in less than five years."

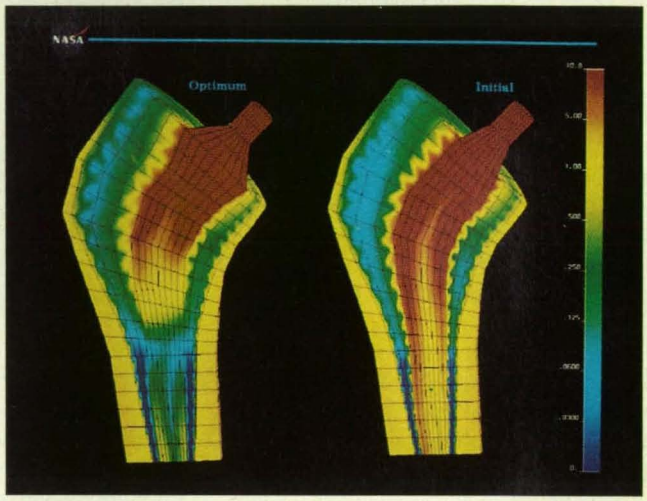


An innovative heat pump uses a non-azeotropic refrigerant as its working fluid.

Lewis Technique Aids Implant Design

Space technology could provide long-term relief for recipients of orthopedic implants. Currently, the service life of prostheses such as replacement hip joints averages just ten years. As a result, many patients face revision surgeries. New implants made of composite materials and designed using NASA CAD software "hold promise for greatly extending implant service lives," according to Dimitrios Saravanos, part of a Lewis Research Center team collaborating with Case Western Reserve University on hip implant research.

Both the composite materials and design technique address the main problem associated with today's implants: the loosening and separation of implant from bone as the result of differences in stiffness. The materials traditionally used, such as titanium and cobalt-chrome alloys, are much stiffer than natural bone and thereby shield it from normal stresses. This leads to atrophy with increasing porosity of the bone tissue, which in turn causes the loosening and failure of the implants. Researchers have determined that continuous fiber laminated composites more closely match the stiffness of natural bone.



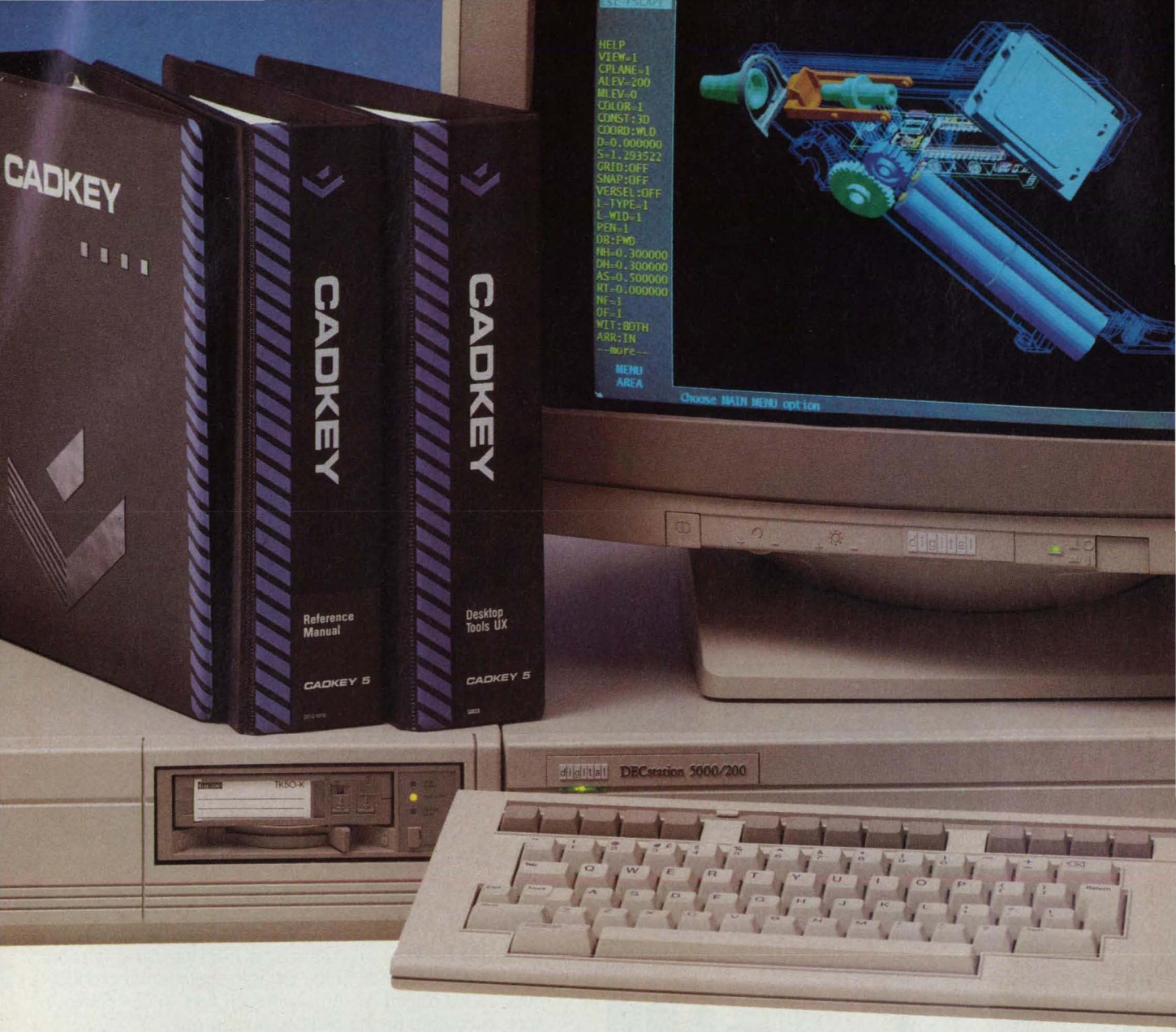
STAT software helps design better hip implants.

Used in tandem with the composites is an analytical model built to simulate the response of the entire system—both bone and implant—to stress. An algorithm adapted from STAT, NASA's optimization code for propulsion components, first determines the relative sensitivity of design variables such as width, length, and the direction of composite layers. It identifies as most sensitive those that, when changed, have the greatest impact on the stress response.

The optimizer then runs a series of simulations, changing all of the variables, but changing the most sensitive ones the most. Conducting finite element analyses of the various combinations of shapes and materials enables it to reject design options resulting in areas of concentrated stress. The process continues iteratively until it converges on an optimal design. "It's an elaborate, systematic search that can easily be generalized," said Saravanos. "We've used the same technique for knee implants."

The technology could help manufacturers to refine and automate traditional implant designs, to facilitate use of advanced fiber composites in improved implants, and possibly to customize implants for individual patients. Saravanos anticipates that expanding computational capabilities will lead to increasingly realistic anatomical models and correspondingly better prostheses. ❑

For more information about the technologies described above, contact the NASA field center that sponsored the research (see page 20).



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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Fabrication of High-T_c Superconducting Integrated Circuits

A new microwave ring resonator demonstrates a process for the fabrication of passive integrated circuits that contain high-transition-temperature superconductors. Such superconductors can increase the efficiencies of communication systems.
(See page 22.)

Hand-Switch Unit for Use With Protective Suit

A water-tight unit designed for use with a protective suit contains two hand-operated switches. The user can grasp and operate the switches without looking at them.
(See page 30.)

Computer Data-Entry System Facilitates Proofreading

A visual optical-electronic display for encoding and measurement is designed to (1) reduce significantly the rate of errors in text or other data entered manually or by optical character-recognition equipment and (2) ease the task of proofreading those data.
(See page 34.)

Video System Highlights Hydrogen Fires

A video system combines images from the visible spectrum and from three bands in the infrared spectrum to produce a color-coded display to show hydrogen fires, which cannot be seen in daylight by the unaided human eye.
(See page 36.)

Scanning Light Sheet Would Measure Deflection of Beam

This apparatus measures linear and angular displacement or deflection of a structure. Besides its use in the aerospace field, the apparatus can be applied in construction, aircraft, shipbuilding, and automotive industries.
(See page 38.)

Field-Domain Ion Spectrometry

A new concept may lead to development of hand-held, low-power, portable devices that could detect parts-per-billion concentrations of airborne chemicals in real time. Possible applications include early detection of toxic gases and vapors, hidden explosives, and illegal drugs.
(See page 46.)

Dimensionally-Stable Graphite-Fiber/Glass Composites

A new method allows control of proportions, orientation, and distribution of fibers in the matrices and for fused bonds between the fibers and the matrices. It is suitable for making low-thermal-expansion platforms for optical instruments.
(See page 54.)

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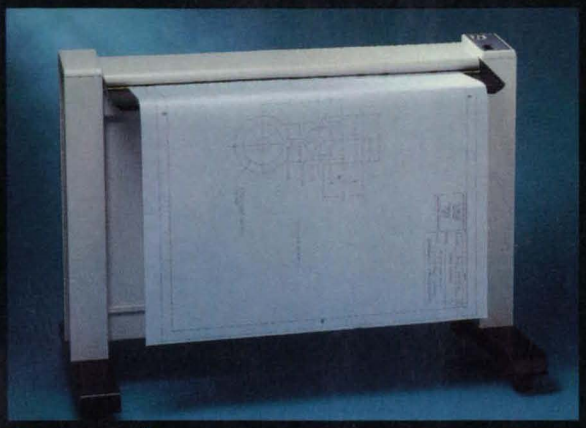

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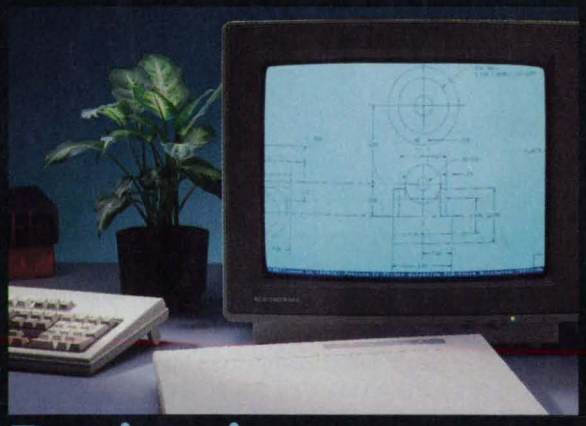

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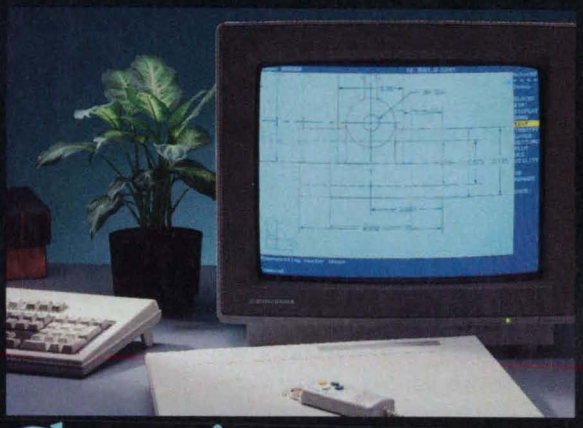

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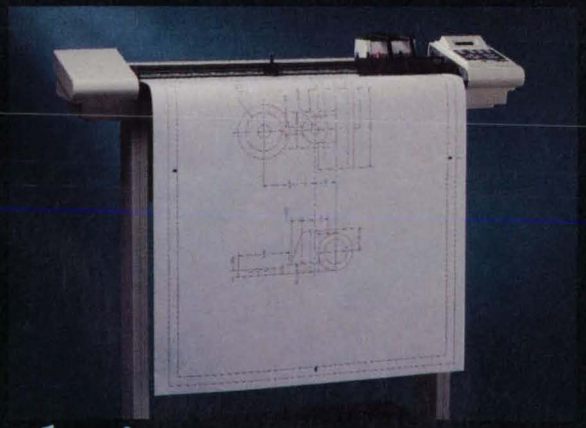

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Isolated Fast High-Voltage Switching Circuit

High-voltage, fast pulses could be useful in many applications.

Marshall Space Flight Center, Alabama

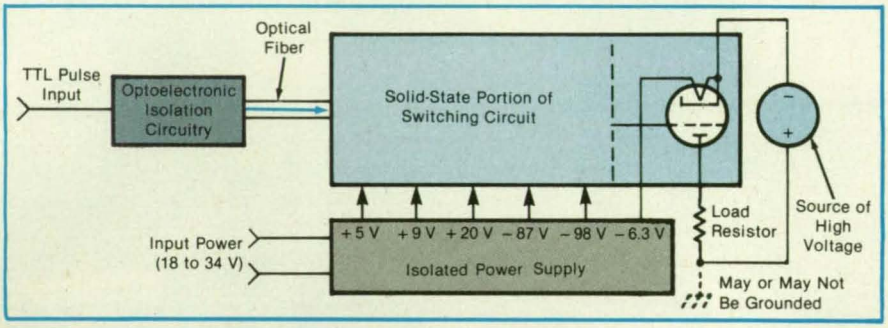
An electrically isolated switching circuit supplies pulses at potentials up to 6.5 kV and currents up to 6.5 A, lasting as long as a few microseconds. The turn-on time is about 40 ns; the turn-off time is about 3 μs. This and similar circuits could be useful in such industrial and scientific applications as high-voltage, high-frequency test equipment; electrostatic-discharge test equipment; plasma-laboratory instrumentation; spark chambers; and electromagnetic-interference test equipment.

Switch-controlling pulses at the transistor/transistor-logic (TTL) level are coupled to the switching circuit via an optical fiber. The solid-state portion of the switching circuit converts the optical pulses back into TTL electrical pulses, amplifies the pulses, and applies them to the control grid of a vacuum tube, which serves as the main high-voltage switching element. An isolated power supply accepts nonisolated input power at 18 to 34 V and feeds isolated voltages of +5, +9, +20, −87, −98, and −6.3 Vdc to the various stages of the switching circuit (see figure).

In a prototype version of the circuit, the isolated power supply features transformer coupling with capability for electrical isolation up to 20 kV. However, the maximum allowable switched voltage is limited by the capability of the vacuum tube to 10 kV. The maximum switched current and the turn-on time are determined in part by the load resistor (two 50-kΩ, 2,000-W resistors in parallel in the prototype). Shorter turn-on time can be obtained by use of a smaller load resistance.

This work was done by Anthony Rizzi of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 96 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-26180.



The High-Voltage Switching Circuit is electrically isolated from the control circuitry by means of a fiber-optic signal coupling and an isolated power supply. Electrical isolation protects both the technician and nearby equipment.

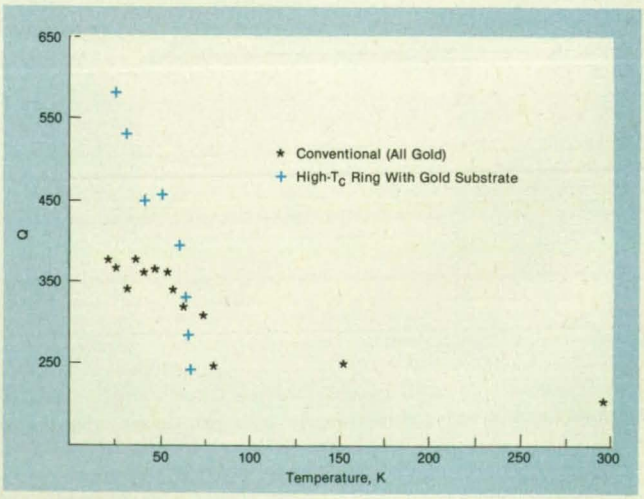
Fabrication of High-T_c Superconducting Integrated Circuits

Superconductors can reduce losses and dispersion in microwave circuits.

Lewis Research Center, Cleveland, Ohio

A microwave ring resonator has been fabricated to demonstrate a process for the fabrication of passive integrated circuits that contain high-transition-temperature (high-T_c) superconductors. Superconductors can increase the efficiencies of communication systems — and particularly microwave communication systems — by reducing ohmic losses and dispersion of signals. They could be used to reduce the sizes and masses and increase the aiming accuracies and tracking speeds of millimeter-wavelength, electronically steerable antennas. High-T_c superconductors are preferable for such applications because they operate at higher temperatures than low-T_c superconductors do, and, therefore, the refrigeration systems needed to maintain superconductivity can be designed to be smaller and lighter and to consume less power.

In the fabrication of the ring resonator, a film of the high-T_c superconductor $YBa_2Cu_3O_{7-x}$ was deposited on one face of a 1-cm-square $LaAlO_3$ substrate by a laser-ablation technique. This technique involves the use of a pulsed ultraviolet laser and an in-situ oxygen annealing subprocess. (The substrate was selected for its compatibility with the deposition process and because it had the desired microwave dielectric properties; in other applications, suitable substrates might include magnesium oxide and cubic zirconia stabilized with 8 percent yttria.) The superconducting film was smooth and of high quality. Part of the film was removed by photo-



A Resonator Made With a High-T_c Superconducting Ring was tested at 35 GHz along with a similar resonator made with a gold ring.

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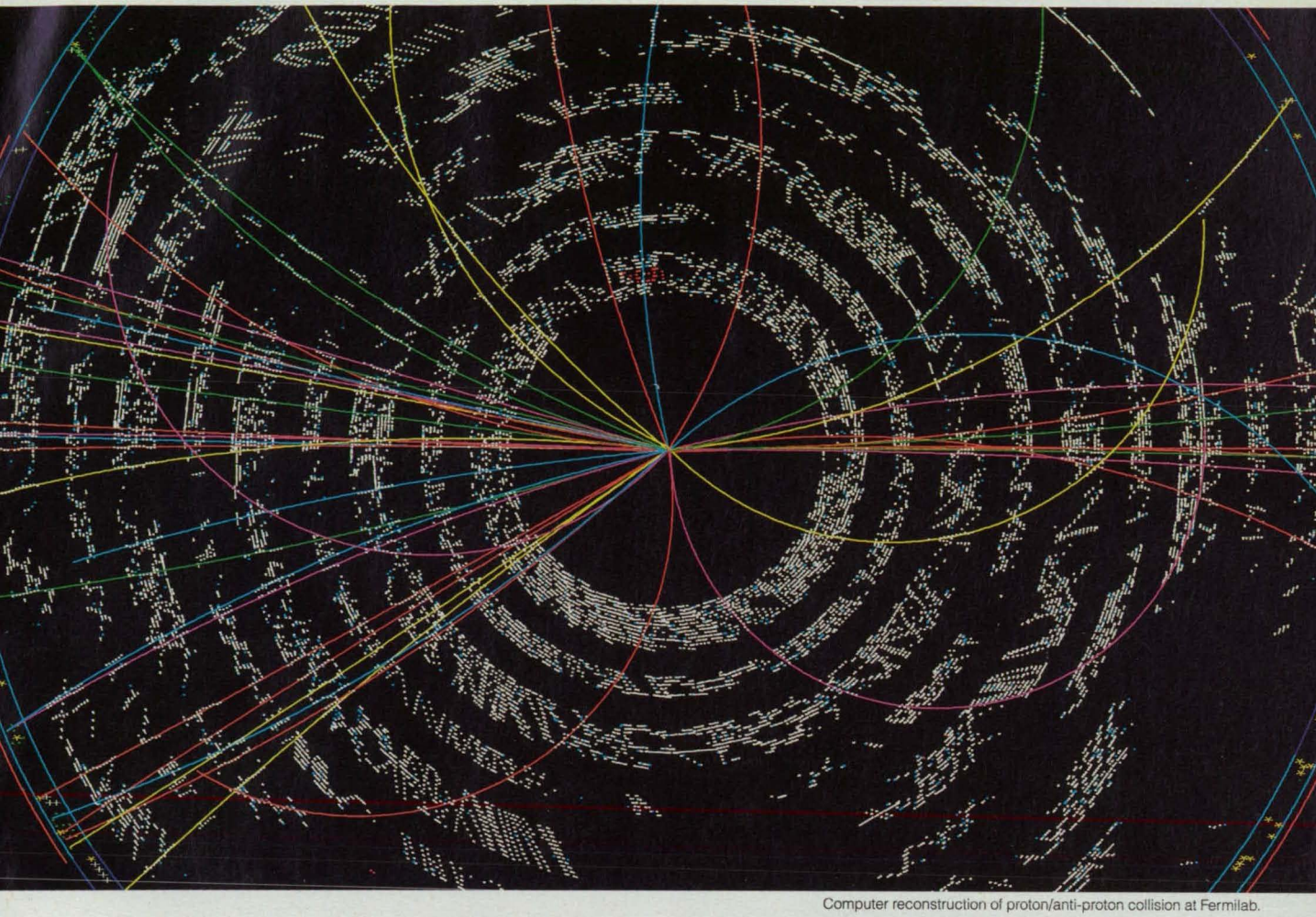

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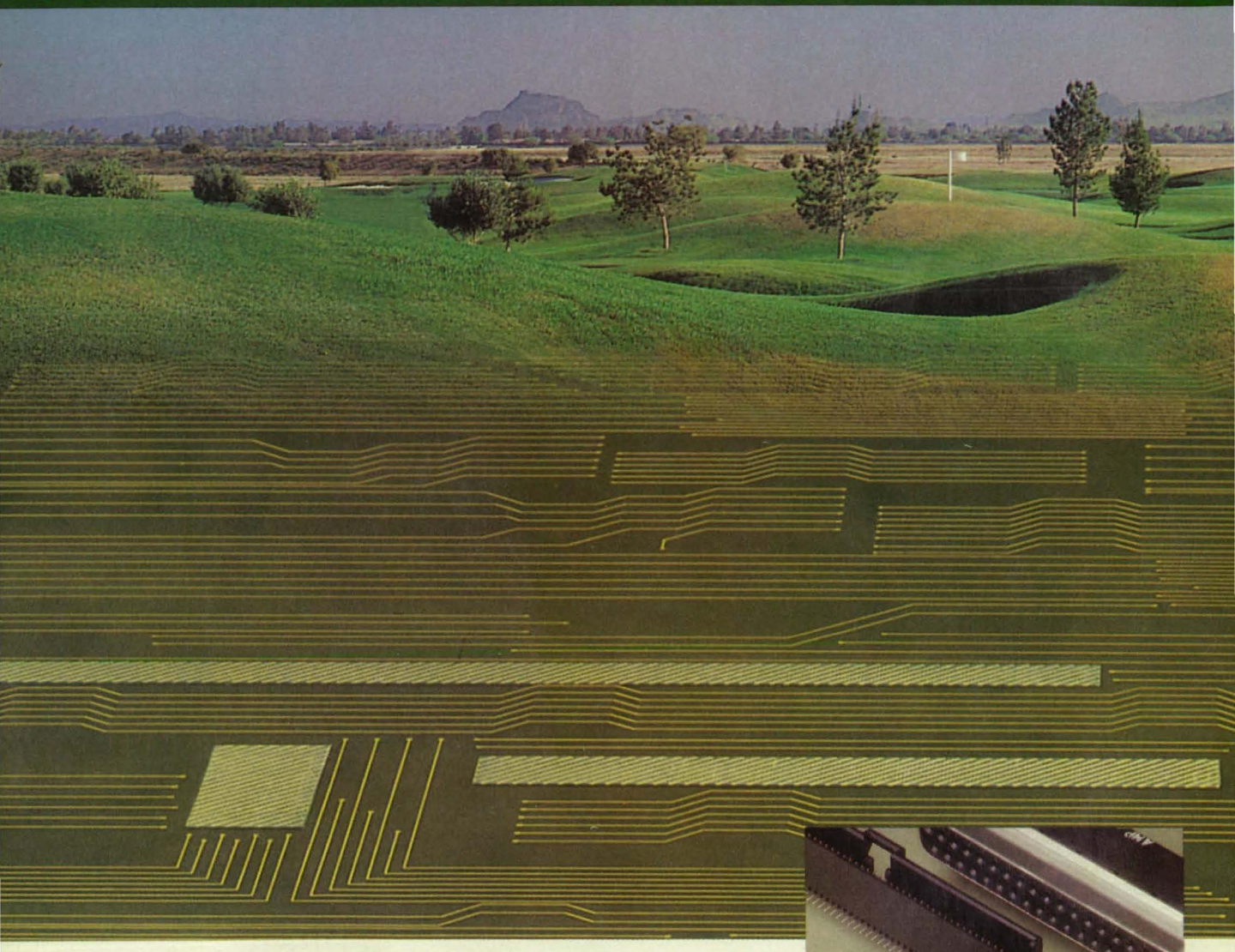

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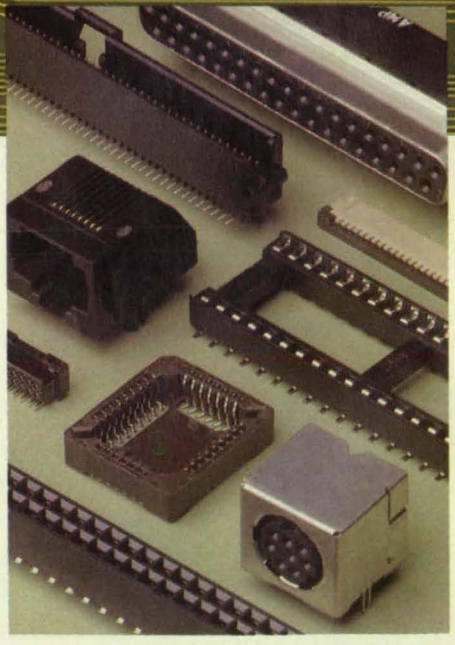

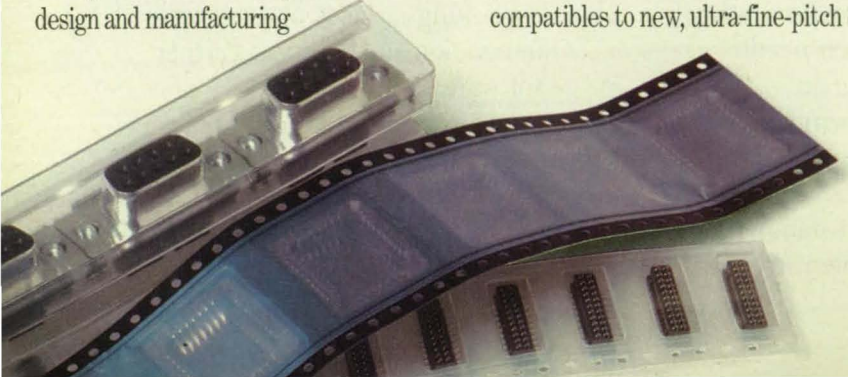

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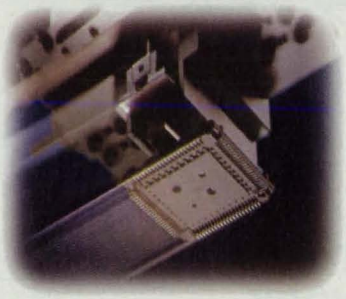

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lithography and etching to form the ring-resonator circuit. A gold film intended to serve as a ground plane was deposited on the opposite face of the substrate.

This ring resonator was connected to a microwave network analyzer, cooled to various temperatures from about 275 down to about 20 K, and tested at frequencies from 26 to 40 GHz. As the figure shows, the Q (the reciprocal of the dimensionless damping parameter: a measure of the resonant quality of the circuit) of the superconducting resonator increased dramatically above that of the conventional gold resonator as the temperature decreased below T_c (approximately 70 K in this case).

This work was done by Kul B. Bhasin and Joseph D. Warner of **Lewis Research Center**. *For further information, Circle 75 on the TSP Request Card.* *LEW-15056*

Testing Metal Chlorides for Use in Sodium-Cell Cathodes

Cyclic voltammetry yields qualitative indications of chemical and electrochemical stability in molten electrolytes.

NASA's Jet Propulsion Laboratory, Pasadena, California

Cyclic voltammetry has been found to yield qualitative indications of the chemical and electrochemical stabilities of metal chlorides in molten $NaAlCl_4$, which is the electrolyte material of a developmental class of sodium/transition-metal-chloride electrochemical cells. It has been conjectured that cyclic voltammetry could be used in conjunction with the measurement of galvanostatic polarization curves to determine whether a given metal chloride would be suitable as a cathode material in such a cell.

Sodium cells that contain transition-metal dichloride cathodes in chloroaluminate melts offer energy and power densities comparable to those of sodium/sulfur batteries, but offer advantages over Na/S cells, including lower operating temperatures, increased safety, and tolerance of overcharge and overdischarge. These cells could be useful in such high-energy-density and high-power-density applications as leveling the loads on electric-power plants, supplying power to electric ground vehicles, and aerospace applications.

The essential requirement for the successful operation of a metal chloride as the cathode in a sodium cell is its insolubility in the molten $NaAlCl_4$ electrolyte, both in the charged state and in the discharged state of the cell. From detailed fundamental studies on ferrous, nickel, and copper chloride electrodes, a correlation has been established between the dc cyclic voltammetric behavior and the chemical and electrochemical stabilities of these metal chlorides in the electrolyte melt.

The ideal voltammetric curve consists of sharp reversible peaks with low oxidation currents subsequent to the peaks. The dissolution of metal during oxidation is inhibited by the deposition of the oxidation product (e.g., a transition-metal chloride) on the electrode. The protective nature of the oxidation product is determined by its chemical and electrochemical stability in the electrolyte and by its microstructure. A low oxidation current subsequent to a peak thus implies an insoluble oxidation product. High oxidation currents subsequent to peaks could be caused either by a porous deposit (in which case the reduction peaks would be comparable in size to the oxidation peaks)

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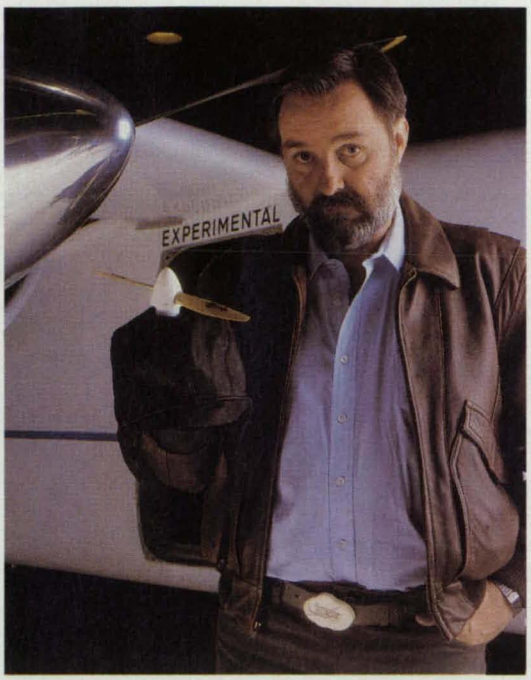

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Engineering drawings courtesy of Burt Rutan/Scaled Composites, Inc.

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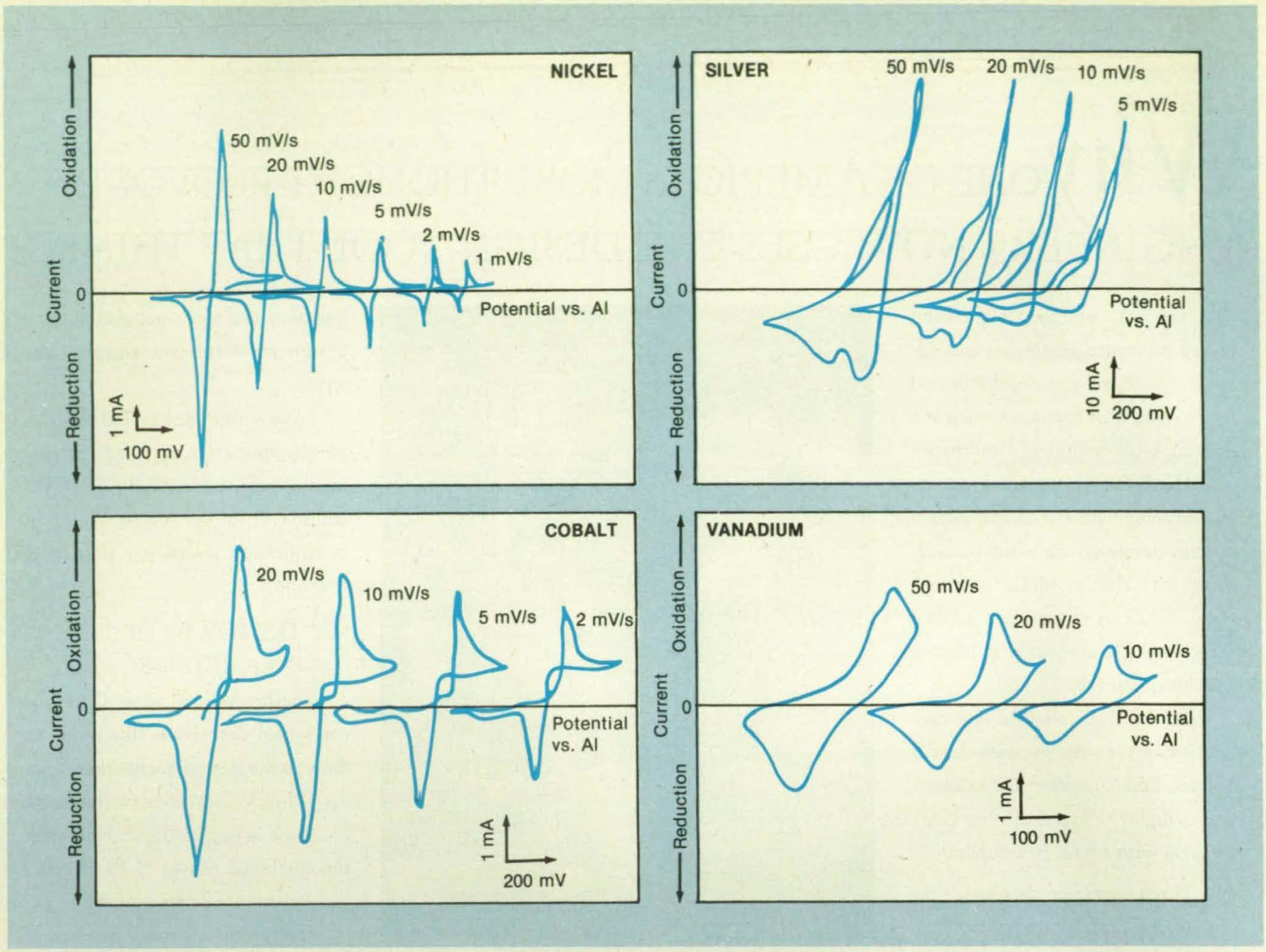

Cyclic Voltammetric Curves of transition-metal wires in molten $NaAlCl_4$ electrolyte can be used to estimate the suitability of these transition metals as cathodes in sodium cells.

or by solubility of the oxidation product (in which case the reduction peaks would be smaller than the oxidation peaks, especially at smaller scan rates).

Nickel (see figure) and, to some extent, iron display nearly ideal voltammetric curves and perform well as cathodes. Copper, on the other hand, exhibits high dissolution currents, especially beyond the second peak, implying solubility of its chlorides (formed in the second step), as also noticed in laboratory $Na/CuCl_2$ cells.

On the basis of the foregoing considerations, several prospective metals have been screened for use as cathodes by testing them in $NaAlCl_4$ electrolyte with a concentric Ni foil as the counterelectrode and a highly pure Al reference electrode with a potential 1.643 V vs. Na^+/Na at 250 °C. Of these metals, manganese, aluminum, and titanium exhibit no distinguishable voltammetric peaks. The cyclic voltammetric curves of silver and vanadium (also shown in the figure) indicate reversible behavior, but the dissolution currents subsequent to the peaks are quite high and the reduction half-cycles are smaller, especially at slow potential-scanning rates. This behavior suggests that the chlorides of these metals may be soluble. The cyclic voltammetric curve of cobalt (at the bottom of the figure) includes sharp, nearly symmetrical peaks, but the high dissolution current suggests a porous deposit, or, less likely, solubility of the cobalt chloride in the electrolyte; in the former case, cobalt chloride would be a promising cathode material. The cyclic voltammetric curves of molybdenum are characterized by the sharp, symmetrical, and reversible peaks and low oxidation currents required for a good cathode material.

This work was done by Ratnakumar V. Bugga, Alan I. Attia, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 42 on the TSP Request Card.*
NPO-18385

Delta-Doped Buried Channels in Charge-Coupled Device

Benefits would be better performance at low temperature and less sensitivity to damage by radiation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Buried-channel charge-coupled devices (CCD's) of a proposed new type would contain multiple thin, highly-doped channel layers instead of the single relatively thick channel layers used at present. Unlike the present buried-channel CCD's, the proposed devices are expected to operate efficiently at temperatures below 77 K. Furthermore, in comparison with the present buried-channel CCD's, the new devices should be less sensitive to damage by radiation.

The figure shows the new (proposed) and old (present) buried-channel doping profiles. In the old profile, the concentration of the dopant is about 4×10^{16} cm^{-3} through a thickness of 0.5 μm. The old devices perform inadequately at temperatures below 100 K because of trapping of charge carriers by impurity atoms. Also, because the packets of signal charge can be relatively wide (1,000 to 3,000 Å) in the relatively thick channels, these packets are more likely to encounter and be captured by defects induced by radiation than they

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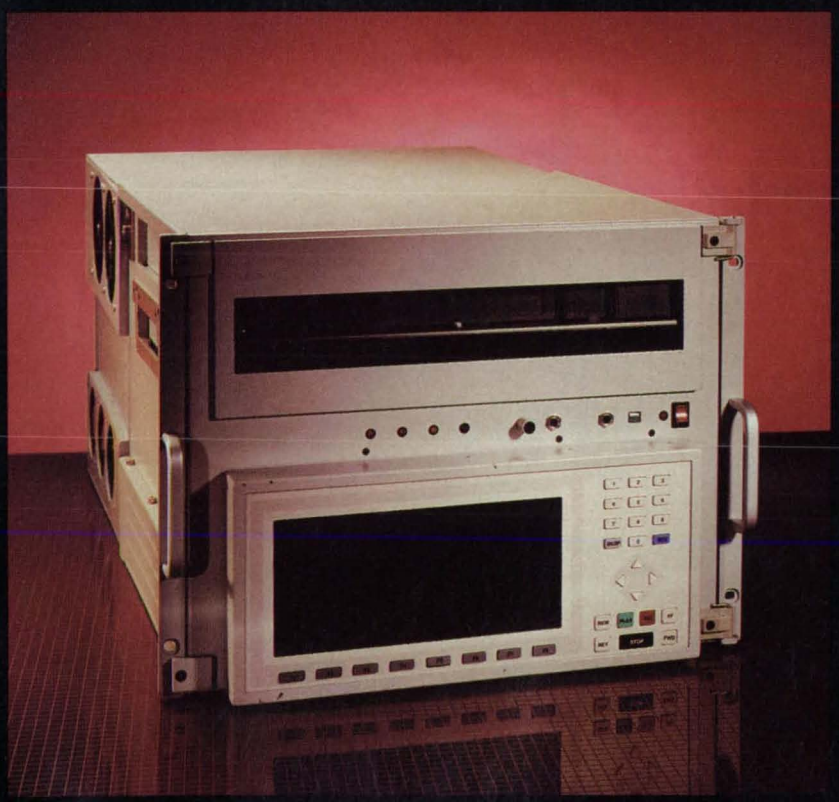

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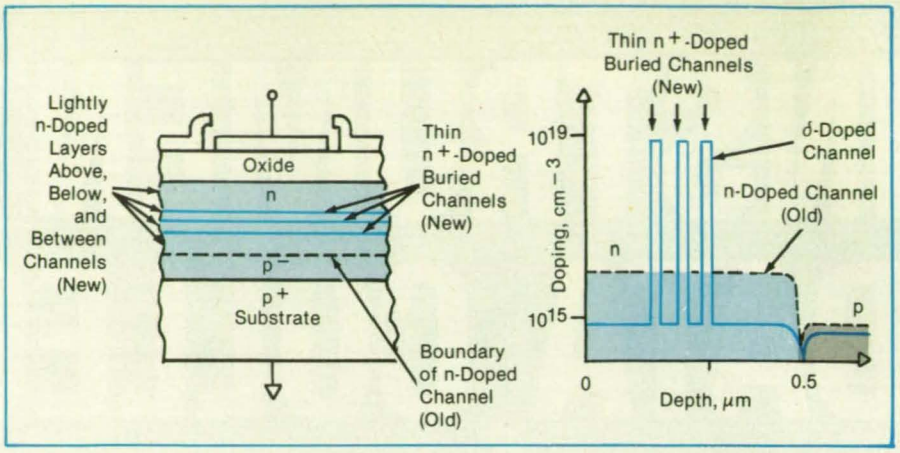
would be if the packets could be made narrower.

The proposed doping profile is called "delta doping," because of the sharply confined, high levels of doping. The new thin buried-channel layers should be doped heavily enough to cause the impurity charge-carrier energy band to merge with the conduction charge-carrier energy band; this would restrict the "freeze-out" effects (which degrade performance at low temperatures) to temperatures from 0 to a few degrees Kelvin. The confinement of the packets of signal charge to thin channel layers should reduce the probability of capture by radiation-induced defects both in the depth of the device and at the surface.

The concentration of dopant and the thickness of each doped layer would be chosen to obtain the desired charge capacities. The position of each doped layer would be chosen to optimize clock-signal-swing and fringing-electric-field effects.



Multiple Thin, Highly Doped Buried Channels would replace a thicker, less-doped channel.

This work was done by Eric R. Fossum of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 57 on the TSP Request Card.*
NPO-18372

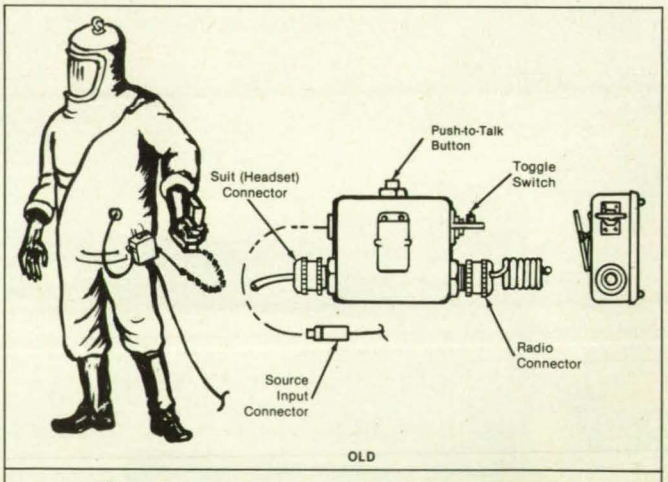
Hand-Switch Unit for Use With Protective Suit

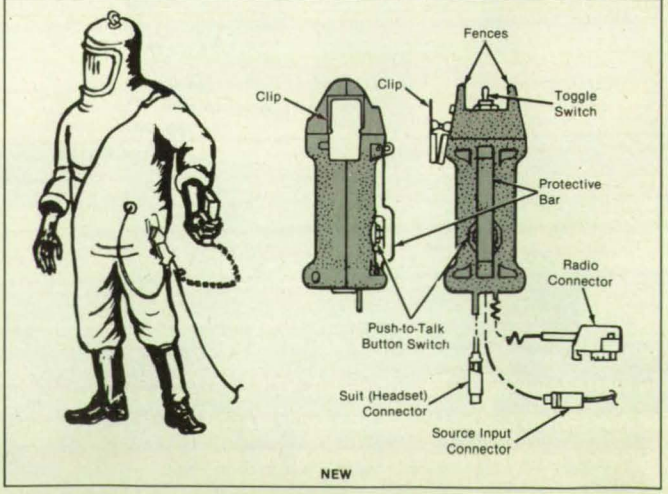
The user can grasp and operate the switches without looking at them.

John F. Kennedy Space Center, Florida

A unit that contains two hand-operated switches is water-tight and designed for use with a protective suit. One switch is a toggle switch that is used to select com-

Fences on Top of the New Unit protect the toggle switch from inadvertent operation. The fences are spaced to accommodate the gloved thumb. The push-to-talk button is protected by a longitudinal bar, which is springy and is compressed inward to actuate the button. On the old unit, the toggle switch and button were exposed.





munication by wire or radio. The other switch is a press-to-talk button.

The unit replaces a square switch box unit that tended to rotate and twist on the suit, forcing the wearer to look at the unit before operating it. In addition, the old unit tended to leak when exposed to fuels, detergents, water, and other liquids.

The new unit (see figure) includes a clip for attachment to the suit or another convenient object. The unit is shaped so that the wearer can grip it easily with one hand without looking. The user can operate the radio-vs.-wire toggle switch with a gloved thumb. The push-to-talk button can be actuated by squeezing a bar against the unit with two fingers, again without looking. The center of gravity of the unit is positioned so that the unit tends to remain in the preferred orientation in which the switches are most accessible to the operator.

The unit has a two-part polycarbonate shell with a male/female inner locking seal between the two parts. The toggle and push-button switches are covered with rubber boots, which seal out gases and liquids. Detergents cannot enter when the protective suit is sanitized, for example.

This work was done by Howard E. Chalson of Lockheed Space Operations Co. for **Kennedy Space Center**. *For further information, Circle 53 on the TSP Request Card.* *KSC-11546*

Hollow Cathode With Multiple Radial Orifices

The current is spread over a larger area.

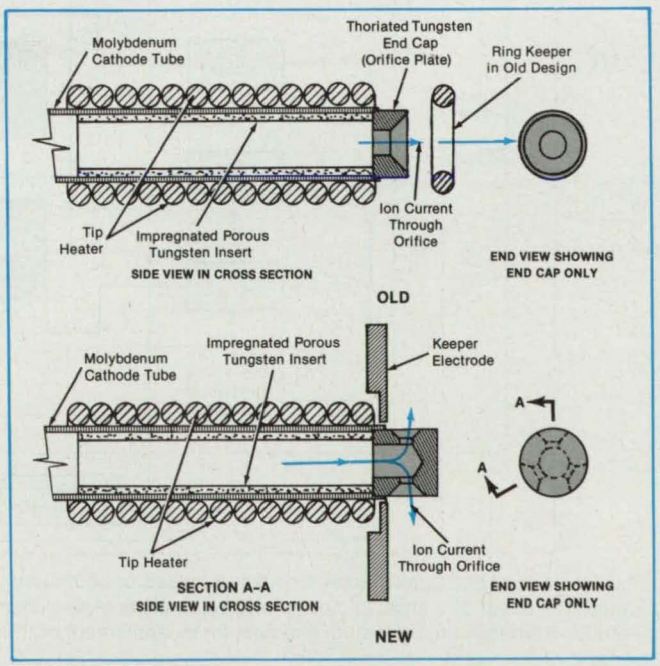
NASA's Jet Propulsion Laboratory, Pasadena, California

An improved hollow cathode that serves as a source of electrons has multiple radial orifices instead of a single axial orifice as in the prior design. The improved cathode is a prototype of high-current (≈20 A) cathodes for ion engines in spacecraft. On Earth, multiple-orifice cathodes could be in large-diameter (≈30 cm) ion sources for industrial processing of materials.

The figure shows the old and new designs. The major disadvantage of the old design is that at the high current density that obtains in a single orifice at a current of about 20 A, a jet of energetic (≈30 eV) ions causes unacceptably large erosion of components located near the cathode. By apportioning the current to multiple orifices, the new design reduces the current through any one of them. This is an important feature because the current through a single orifice is believed to be a principal parameter that affects the formation of the destructive jet of energetic ions.

Of course, the radial orientation of the orifices in the new design causes the current to be dispersed radially in the vicinity of the cathode. This is an advantage where, as in many cases, it is desirable to produce a plasma that is more nearly uniform over a wider region around the cathode.

This work was done by John R. Brophy of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 54 on the TSP Request Card.* *NPO-18509*



Multiple Radial Orifices in the new cathode help to distribute the ion current more smoothly, over a larger area.

Electronic Load Bank

Power field-effect transistors in parallel provide low resistance.

Lewis Research Center, Cleveland, Ohio

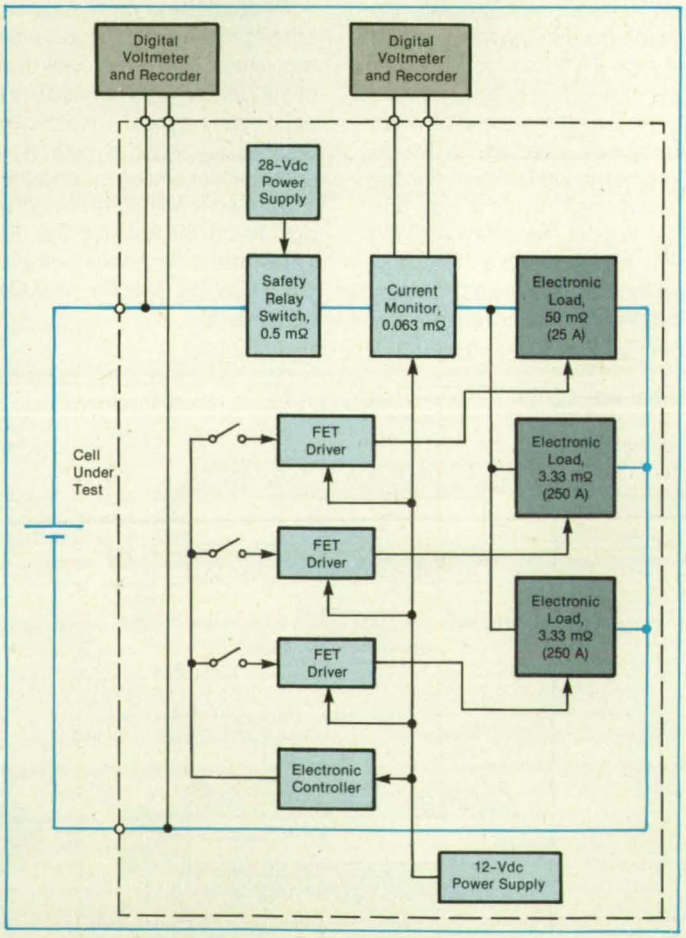
An electronic load-bank circuit acts as a controlled short circuit for use in testing single 1.2-V Ni/H_2 or other low-voltage electrochemical cells. When the entire load bank is switched on, the circuit presents a total resistance of about 2.2 mΩ to the cell; consequently, at the nominal cell-output potential of 1.2 V, the circuit draws a maximum current of about 525 A.

The figure is a simplified block diagram that illustrates the main subassemblies of the circuit. The electronic load bank is a set of power metal oxide/semiconductor field-effect transistors (MOSFET's) connected in parallel. One of these load transistors can be driven on alone to draw a current of 25 A, and/or the others can be switched on in two groups to provide two increments of 250 A. Thus, by setting switches to turn on various combinations of FET drivers, one can select load currents of 25, 250, 275, 500, or 525 A.

The FET drivers are, in turn, driven by a control circuit. By use of a switch, the operator can select a continuous or pulsed load. By use of a potentiometer, the operator can adjust a timer in the control circuit to vary the duration of the pulse from 0.1 to 1 s. In pulse mode, the operator initiates the pulse by pressing a "start" switch.

The circuit includes a voltage tap for measurement of the cell-output potential. Another voltage tap provides for measurement of the load current in terms of the potential across a 0.063-mΩ resistor in series with the load. A safety relay switch is placed in the high-current path between the cell under test and the load. The relay circuit includes a light that indicates when the switch is closed. This light provides an extra warning to the operator: it could be dangerous to connect or disconnect the cell while the switch is closed and the light is on.

This work was done by Steven W. Huston of Rockwell International Corp. for **Lewis Research Center**. *For further information, Circle 23 on the TSP Request Card.*
LEW-15036



The **Electronic Load-Bank Circuit** provides a pulsed or continuous low-resistance load to imitate the effect of a short circuit on a Ni/H_2 or other electrochemical power cell. It also includes a safety/warning feature and taps for measurement of the cell-output voltage and current.

Fast Pixel Buffer for Processing With Lookup Tables

Processing would be faster than when reading, one pixel at a time, from image memory.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed scheme for buffering data on the intensities of the picture elements (pixels) of an image would increase the rate of processing beyond that attainable when the data are read, one pixel at a time, from the main image memory. The scheme would be applied in the design of specialized image-processing circuitry; for example, a convolution processor in which the data from the pixels in a rectangular window smaller than the full image are multiplied by specified factors, then added and subtracted to obtain a datum that would be assigned to a central or other designated pixel in the window. The scheme is intended to optimize the performance of a processor in which the electronic equivalent of an address-lookup table is used to address those pixels in the main image memory that are required for processing.

The scheme exploits the fact that usually (as in the case of a rectangular window), after access to a given pixel in memory has been gained, the next pixel to which access is required lies within a small area that includes the given pixel. Therefore, in this scheme, whenever the datum of the pixel at location x, y is read from the main memory, the data of the pixels in the rectangular area defined by the next n pixels in x and the next m pixels in y are also read and stored in a fast-access buffer memory called a "pixel buffer" or "pixel cache."

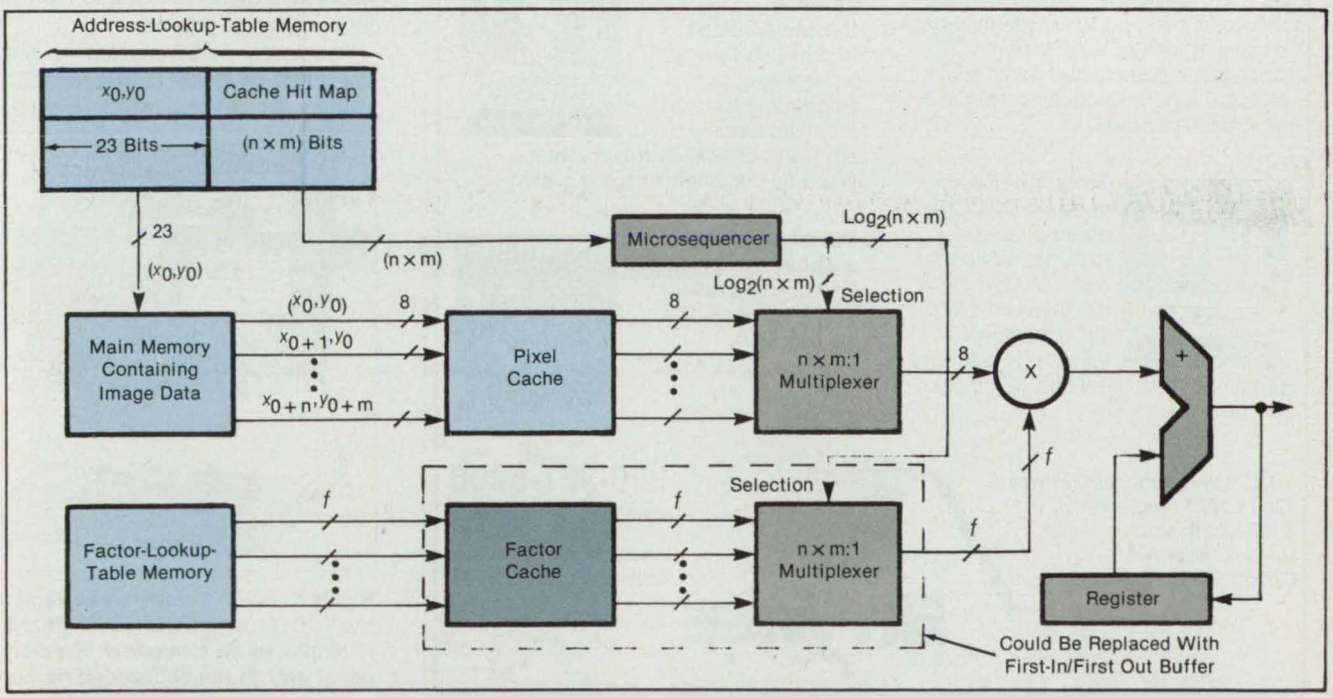
The contents of the address-lookup-table memory would be altered to take advantage of the prior knowledge of which pixels are in the pixel buffer and which of them are needed for processing. This knowledge would be encoded in the form of a cache hit map, in which a single bit would represent each location in the pixel cache — a 1 designating each pixel to be used and a 0 designating each pixel not to be used.

Thus, the contents of the address-lookup table would include the address of a desired pixel plus the cache hit map of the associated group of $n \times m$ pixels in the pixel cache. The cache hit map would replace what has been, in a typical prior buffering scheme, the stored addresses of the next pixels in the $n \times m$ region to which access is required. This is an important feature in that it reduces the overall memory bandwidth of the address-lookup table because one reading from this table can result in the simultaneous readout of as many as $n \times m$ pixels.

The contents of the cache hit map would be fed to a programmable microsequencer, which would use the cache hit map as an address and jump to a particular sequence. The output of the microsequencer would control a multiplexer, which would command the output of data on the desired pixels from the pixel cache. Unlike some prior buffering schemes that involve reading data out of first-in/first-out buffers and discarding the unneeded data, this scheme does not waste time reading the unneeded data.

In the version of the scheme illustrated in the figure, the factors by which the pixel data were to be multiplied would also be buffered or cached in a factor-lookup-table memory in the same manner as that of the pixel data. There would be one set of $n \times m$ factors for each entry in the address-lookup table, except that factors that corresponded to pixels not to be used could be replaced by fictitious data. Alternatively, the factor-buffering or -caching feature described above could be replaced by a first-in/first-out buffering scheme, which would require less memory but might operate more slowly when most of the bits in the cache hit map were set to 1.

This work was done by Timothy E. Fisher of **Johnson Space Center**. *For further information, Circle 67 on the TSP Request Card.*
MSC-21896



The **Fast Pixel Buffer** would speed the readout and processing of image data in a lookup-table-driven image processor.

Computer Data-Entry System Facilitates Proofreading

Accuracy is increased and stress is reduced.

Marshall Space Flight Center, Alabama

The visual optical-electronic display for encoding and measurement (VODEM) is a system of computer data-entry and display equipment and associated software (see Figure 1). It is designed to (1) reduce significantly the rate of errors in text or other data entered manually or by optical character-recognition equipment and (2) ease the task of proofreading those data. In addition, the VODEM enables quantitative measurements of the accuracy of data and the performance of each operator. The levels of accuracy achieved with the VODEM exceed those of older systems used to verify data.

The VODEM provides a head-on display that includes the two texts or sets of data to be compared. This relieves the operator of the stress of side-to-side motion between, say, an original document and the digitized version displayed on a video screen.

The VODEM has been developed in a large-screen and a small-screen version that differ mainly in the display equipment. The large-screen version includes a cathode-ray-tube video display; the small-screen version includes a smaller liquid-crystal display mounted on a computer-controlled *x*–*y* drive. The large-screen version is preferred because it offers the highest resolution (thereby facilitating verification of printed characters by operators) and the closest juxtaposition of images.

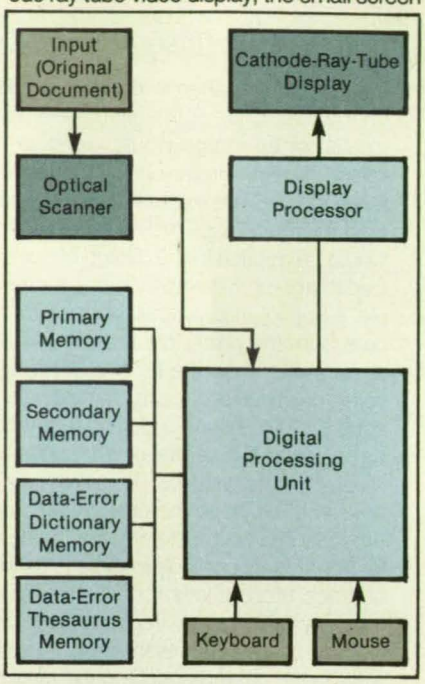


Figure 1. The **VODEM** preprocesses and displays data during data-entry and proofreading tasks in a manner that facilitates the discovery and elimination of errors.

In the large-screen version, the entry of data begins with the acquisition of a bitmap image of the original document by use

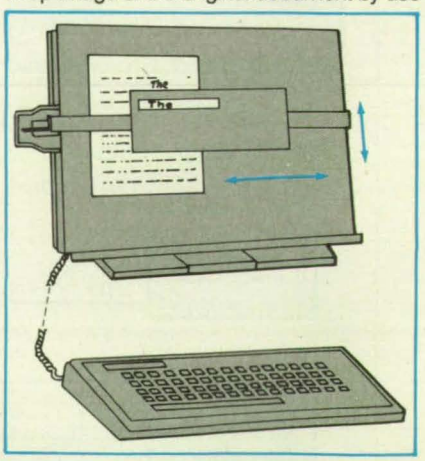


Figure 2. In the **Small-Screen Version** of the VODEM, a portion of the digitized text is displayed on a movable liquid-crystal panel next to the corresponding portion of the original document.

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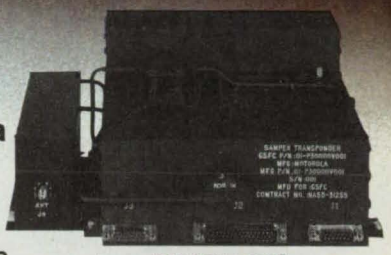
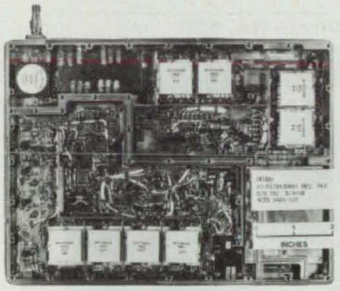
And now, Motorola is producing the third generation **Tracking and Data Relay Satellite System** (TDRSS) transponders. Second generation TDRSS transponders are already providing data transmission on the Gamma Ray Observatory (GRO), Cosmic Background Explorer (COBE) and Extreme Ultraviolet Explorer (EUVE).



NASA Standard Transponder

Motorola produces high reliability, very high data rate modems, operating above 1 Gbps. A Motorola **Integrated Modem** can be customized to include multiplexing, forward error correction, coding, embedded Com munication Security (COMSEC) Transmission Security (TRANSEC), as well as complex modulation/demodulation formats and LO generation.



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of an optical scanner. This image is displayed on the video screen. A display processor overlays a movable data-entry-window image on the image of the original text. The data-entry window displays the data entered by the operator via the keyboard adjacent to the corresponding portion of the original text. The display processor computes the scale of the character font in the data-entry window to approximate that of the image of the original document. In the proofreading mode, the display again includes the image of the original document, and the moving window contains the corresponding portion of the data previously entered via the keyboard.

In the small-screen version (see Figure 2), the original document is placed on the table that contains the *x-y* drive. Like the moving window image in the large-screen version, the liquid-crystal display shows the data entered manually by the operator in any of a variety of sizes to approximate the scale of the character font or handwriting on the document. The software enables the operator to control the position of the display through the keyboard: specifically, to align a cursor on the display panel with that part of the original text that corresponds to the information in the display. The liquid-crystal display also shows the commands that enable the operator to move the display. The small-screen version can be particularly helpful in entering data from documents that cannot be subjected easily to optical scanning. It can also be useful where there is no need to capture data optically for storage.

This work was done by John Woo, Jr., and Daniel N. Woo of Gamma Research, Inc., for **Marshall Space Flight Center**. *For futher information, Circle 2 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

John Woo, Jr.
Gamma Research, Inc.
904 Bob Wallace Ave.
Suite 212
Huntsville, AL 35801

Refer to MFS-26166, volume and number of this NASA Tech Briefs *issue, and the page number.*

Video System Highlights Hydrogen Fires

The video display shows hydrogen fires in red.

John F. Kennedy Space Center, Florida

A video system combines images from the visible spectrum and from three bands in the infrared spectrum to produce a color-coded display in which hydrogen fires can be distinguished from other sources of heat. Because they produce very little light in the visible spectrum, hydrogen fires cannot be seen in daylight by the unaided human eye. Undetected, such fires are hazardous to people and equipment.

Although ordinary commercial infrared video cameras produce images of hydrogen fires, they also produce images of other fires, hot objects, and reflections of the Sun. These sources of infrared radiation have different spectral signatures, between which ordinary commercial video cameras cannot distinguish. Most notably, a hydrogen fire produces water, and therefore its emission spectrum consists mainly of spectral lines indicative of vibrations of water molecules, including a prominent line at a wavelengfth of 2.8 μm. Similarly, carbon-based fires emit radiation charac-

teristic of vibrations of carbon dioxide molecules, in a wavelength band centered at 4.3 μm.

The camera in this video system includes a linear array of 64 discrete lead selenide mid-infrared detectors that operate at room temperature. A scanning mirror sweeps the field of view across the array to generate a full image. Three separate infrared images are obtained with band-pass filters and stored in sequence in memory. The stored images from the 2.4- to 3.2-μm, 3.3- to 4.0 μm, and 4.1- to 4.6-μm bands are used to generate red, green, and blue images, respectively. These images are overlaid on a black and white image of the same scene from a standard commercial video camera.

In the final image, hydrogen fires appear red; carbon-based fires, blue; and hot objects, mainly green and combinations of green and red. Where no thermal source is present, the image remains in black and white. The system has been tested and found to enable a high degree of discrimination between hydrogen flames and other thermal emitters.

This work was done by Robert C. Youngquist, Stuart M. Gleman, and John S. Moerk of Boeing Aerospace Operations for **Kennedy Space Center**. *No further documentation is available.*
KSC-11534

Laser-Power Controller

Durations and numbers of pulses can be controlled.

Lyndon B. Johnson Space Center, Houston, Texas

The electronic system illustrated schematically in the figure enables a technician to exert precise control over the energy radiated by a CO_2 laser of medium power. The laser is operated in bursts, each burst being a sequence of pulses. The energy in each pulse and, therefore, the average power during a burst, can be increased or decreased by increasing or decreasing the duration of each pulse. At a given pulse-duration setting, the average power during a burst is also proportional to the pulse-repetition frequency. The total energy in a burst can be controlled by setting the duration of each pulse and either the number of pulses in the burst or the pulse-repetition frequency and duration of the burst.

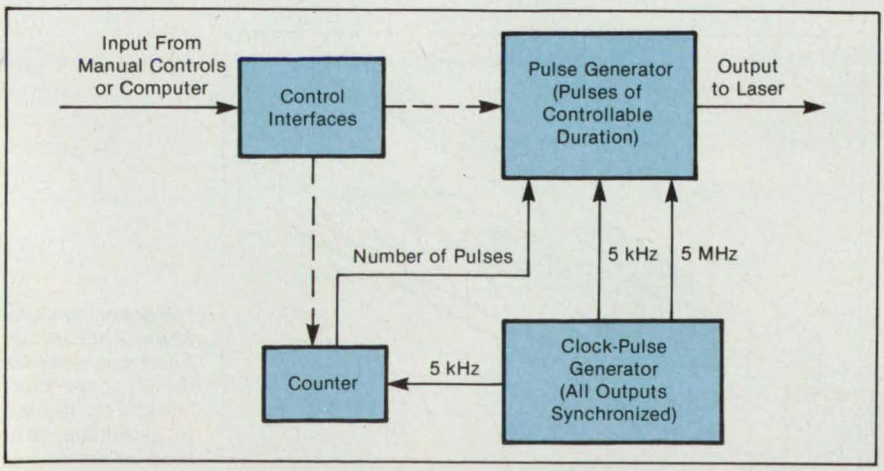
Heretofore, power to the laser was controlled by a commercial laser controller, which is a fixed-frequency, variable-duty-cycle pulse generator. This controller was found to be inadequate in four ways:

1. A separate instrument was needed to set the duration of each burst.
2. The resolution of the laser-beam-power setting was limited.
3. The controller contained analog timing circuits, the stability of which was limited.
4. The resettability of timing was limited.

The new controller is used in place of the commercial controller. It provides the precision and simplicity of digital settings, and all timing is determined by digital circuits. A built-in circuit counts the number of pulses in, and thereby provides control over, the duration of each burst; this duration can be set at a precise value within a wide range. The duration of each pulse can also be set precisely.

The controller is easily adaptable to computer control: a single switch can be used to select either manual or computer control. Another single-switch selection feature provides a choice between counting of pulses in, and manual timing of, bursts.

This work was done by William C. Smith of Lockheed Engineering and Sciences Co. for **Johnson Space Center**. *No further documentation is available.*
MSC-21923



This **Laser Controller** supplies power to a CO_2 laser in bursts, each burst containing a preselected number of pulses of preselected duration.

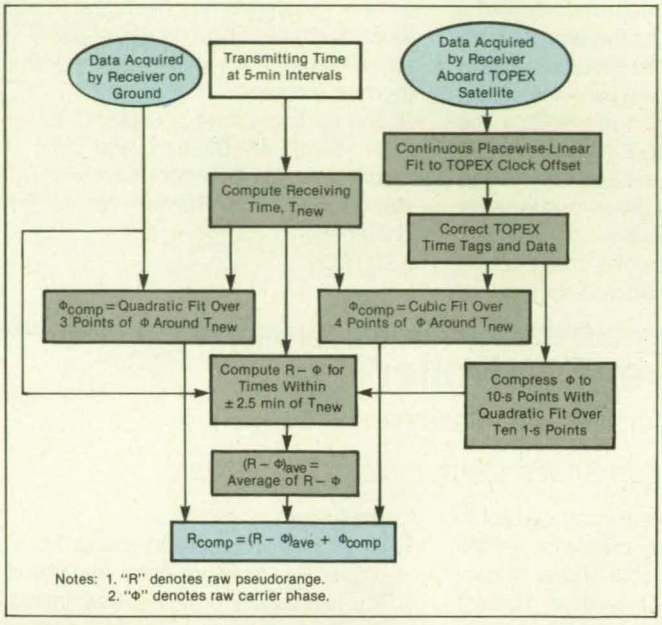
Reducing S/A Errors in TOPEX GPS Measurements

Errors would be reduced in postprocessing by interpolation and smoothing.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed scheme for postprocessing of data acquired by receivers monitoring broadcasts from Global Positioning System (GPS) satellites would reduce those errors in the computed positions of the receivers that are caused by pseudorandom offsets introduced into the transmitted signals. These offsets can be canceled exactly with the help of codes available to privileged users and are intended to degrade the accuracies available to nonprivileged users, pursuant to a policy called "selective availability" (S/A). The proposed scheme was devised primarily for GPS receivers aboard the TOPEX satellite (the joint U.S./French Topography Experiment satellite) and for GPS receivers at associated ground stations.

The S/A reduces the user's positioning accuracy in two ways: first, artificial offsets are added onto the broadcast GPS ephemerides, and second, the GPS clocks that generate the carrier phase and coded signals are dithered. Only the second aspect will affect the computation of the TOPEX orbit because real-time operation is not needed. The effects of the S/A clock dithering can, in principle, be removed by differencing between receivers observing the same GPS satellites, but this requires accurate synchronization of all receiver clocks. In the case of TOPEX, there are two sources of imperfect clock synchronization. The first and larger source is the constant drift of the clock on board the TOPEX satellite, which drift can cause a residual effect as large as 10 cm on the TOPEX carrier phase and 1 m on the TOPEX pseudorange. The second source is the difference between the times of propagation of GPS signals from the same satellites to different receivers. This difference can give rise to range measurement errors of the order of millimeters.



This **Data-Compression Scheme** would govern the postprocessing of signals acquired by receivers aboard the TOPEX satellite and on the ground. The scheme would reduce S/A errors in the computed positions of the receivers.

The proposed postprocessing (data-compression) scheme incorporates a low-order polynomial interpolation and carrier-phase smoothing of pseudorange data acquired by the TOPEX-satellite and ground-station receivers (see figure). For the purposes of this scheme, it is assumed that the carrier phase has been converted to the same unit (length) as that of the pseudorange and that the clocks of all ground-based receivers are synchronized within 1 ms. According to a computer simulation, both (1) the S/A error on the differential pseudorange and carrier phase and (2) the error attributable to nonsimultaneity of reception, that would remain after compression by use of the scheme, would be < 0.1 mm.

This work was done by Sien-Chong Wu, William I. Bertiger, and Jiun-tsong Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 77 on the TSP Request Card.*
NPO-18326

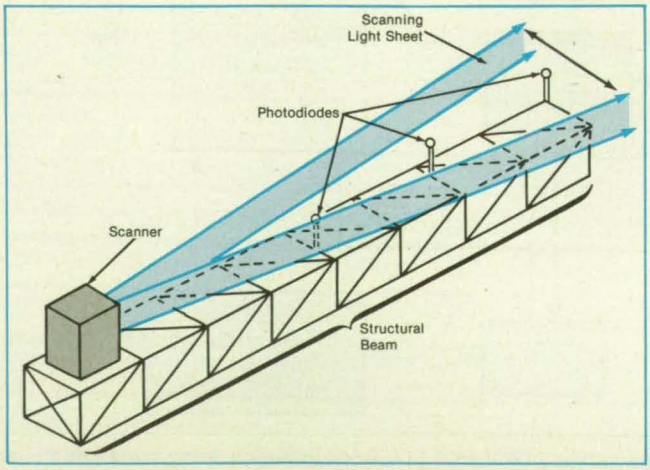
Scanning Light Sheet Would Measure Deflection of Beam

A nonintrusive optical apparatus would measure displacement accurately.

Langley Research Center, Hampton, Virginia

A scanning-light-sheet apparatus has been designed to measure the linear and angular displacement or deflection of a structure. Prior apparatuses for this purpose have included linear displacement transducers, which require physical contact between portions of the structure (thus modifying the behavior of the structure) and accelerometers and strain gages, which do not measure deflection directly. With the scanning-light-sheet apparatus, the measurements are made by optical means.

The apparatus is intended specifically to measure the deflection of a beam-shaped truss structure. It includes a conventional low-powered laser, lenses, mounts, a single-axis optical scanner, several photodiodes, and an electronic controller. As illustrated



The **Scanning-Light-Sheet/Photodiode Apparatus** measures motion of the structure and can be used to determine positions, deflections, and velocities.

in the figure, the laser is mounted at one end of the beam while photodiode targets are located at several stations along the beam. A collimated vertical light sheet, about 1 in. (2.5 cm) wide, is generated with suitable optics. The single-axis optical scanner is used to oscillate the light sheet and sequentially illuminate the photodiode targets.

The relative lateral displacements between the scanner and the targets can be determined from the angular positions of the scanner at instants when the targets are illuminated or from the time intervals between illumination of the targets and a reference target, which is mounted next to the scanner. Because this is a line-of-sight apparatus, multiple photodiodes can be used to monitor the displacements at different stations as long as the targets are mounted so as not to shadow each other. Inasmuch as the scanning rate is over 300 Hz, dynamic measurement is also possible. Test results from a bench model built indicated that the precision in displacement measurement was better than 0.01 in. (0.25 mm) at a distance of over 16 feet (5 m). The range of motion was two inches (5 cm), and the data were taken at a rate of 30 Hz.

A horizontal light sheet can be added to make vertical measurements of the beam. Electronically, the two light sheets can be multiplexed to illuminate the same targets to provide both vertical and lateral displacement information of the structure. A laser diode could also be used to reduce the weight and size of the conventional laser.

This apparatus is nonintrusive and enables the direct measurement of the positions of discrete points on a structure. The measurements of positions as functions of time enable the determination of positions, deflections, and velocities. Besides use in the aerospace field, displacement measurements have many applications in the construction-equipment and automotive industries.

This work was done by Ping Tcheng, James H. Monteith, Michael D. Weisenborn, John M. Franke, and Thomas L. Jordan of **Langley Research Center**. *For further information, Circle 40 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14218.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Precise Applications of the Global Positioning System

The theory, history, status, and anticipated uses of the GPS are summarized.

A report presents an overview of the Global Positioning System (GPS) — the constellation of U.S. defense navigation satellites and associated ground stations. The report emphasizes those aspects of the theory, history, and status of the GPS that pertain to its potential utility for highly precise scientific measurements. Current and anticipated applications of this kind include measurements of crustal motions in seismically active regions of the Earth, measurements of the rate of rotation of the Earth and the orientation of the poles, tracking of non-GPS spacecraft in orbit around the Earth, surveying, measurements of radio-signal-propagation delays, determinations of coordinates of ground stations, and transfer of precise time signals worldwide.

The report includes an introduction that discusses techniques and equipment available to users at different levels of authorization to determine the locations of terrestrial, airborne, and spaceborne platforms. Included in this discussion are the GPS codes, the encryption of GPS data to limit the precision available to unauthorized users, and techniques for partial recovery of precision without access to decryption keys.

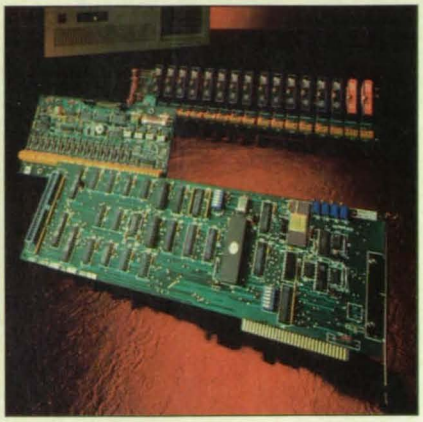
The introduction is followed by a section on high-precision GPS tracking. This section opens with a review of least-squares estimation techniques, corrections for "bumps" in the gravitational field of the Earth, the effects of drag and solar-radiation pressure, and other refinements that have been incorporated to enable the computation of GPS orbits to the required high accuracies.

Next, the applications mentioned previously are discussed, with descriptions of preliminary results where available. The last section of the report summarizes anticipated future developments. These include GPS receivers that are more accurate, weigh less, and cost less in comparison with those now in use; antennas with enhanced suppression of multipath fading; and improved algorithms that can handle the large expected flow of GPS data.

This work was done by Stephen M. Lichten of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "High Precision Applications of the Global Positioning System," Circle 51 on the TSP Request Card.*

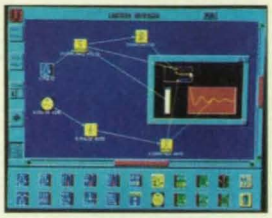
NPO-18397

CyberResearch System of the Month Features RTI® DAS from Analog Devices



Package includes LABTECH NOTEBOOK

The **RTI** series of data acquisition boards were designed by **Analog Devices** with industrial users in mind. With the lowest failure rate in the industry, these are the boards to choose when reliability is critical. Designed from the outset to be compatible with the full line of Analog Devices' signal conditioning modules, RTI boards can be used for the broadest possible range of data acquisition applications.



Labtech Notebook

CyberResearch has now made this top-of-the-line product affordable for everyone. By bundling an **RTI 815A** together with **LABTECH NOTEBOOK®** software at one low price, we've saved over $500 and made it possible for you to afford the very best.

Each combination package includes:

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For More Information Circle No. 364

VGA to Video Converter — VGA to your VCR

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- True, precise NTSC/PAL video timing.
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#NTSC 200 TapeCaster – NTSC Video Output (For use with VCR's in the U.S.A.).....$**750**
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For More Information Circle No. 375

Low-Cost Multiplexers Provide More Channels

Taking measurements to ensure that a process is within specifications can often involve far more than the 16 sensors a data acquisition board is designed to monitor. If you have 40 test points, you'd normally need three LSDAS-16 boards to monitor all of them.

Now **Analogic** has a more affordable solution. The new **MUX 16TC** multiplexes 16 differential low-level analog signals to one A/D board channel. **MUX 16TCEX** panels may be daisy-chained off of the **MUX 16TC** to provide *up to 128 channels* in all, sampled by a single **HSDAS** or **LSDAS** data acquisition board. The **MUX 16TC** allows full access to the remaining A/D, D/A, and Digital I/O channels on your DAS board, with Cold Junction Compensation on either a DAS board input or on a multiplexer channel. C software driver libraries included free.

#MUX 16TC 16-Channel Thermocouple/Low-Level Analog Multiplexer.....$**399**
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For More Information Circle No. 365

Motion Control Systems make Motor Control Easy

PC-based motion control may seem like science fiction to many people. Here at CyberResearch, it's one of our specialties. It can also cost a lot less than you think. Shown here is our **CMCS 222A** complete motor control system, which includes:

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- ***Electrostatics*** Regulated DC Power Supply
- Screw Terminal Panel with Cabling

Designed for a maximum holding torque of 125 ounce-inches, this system is perfect for many applications. It is rated for speeds of up to 7,000 steps-per-second (at 20% of holding torque.)

#CMCS 222A High Torque, 2-axis Size 23 Stepping Motor Control System...$**1595**

For More Information Circle No. 370

New PC Products for

PC Systems Handbook for Scientists & Engineers

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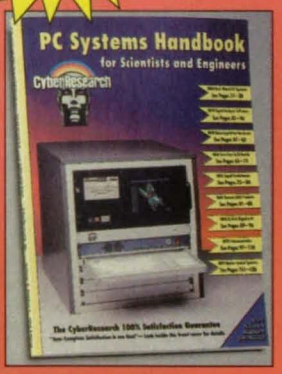

This Combination Tutorial/Catalog Includes Many Examples of PC-based Scientific & Engineering Systems

Have you wanted to enjoy the many benefits of configuring your own PC-based Data Acquisition or Instrumentation system, but didn't know where to begin? The **PC Systems Handbook** will lead you every step of the way, explaining all aspects of systems configuration with easy-to-understand text and clearly documented diagrams. A detailed glossary and two dozen "Tech Notes" help you understand the terminology. Our new **1993 Edition** will be expanded to 196 pages with a hard spine, making it suitable as a permanent addition to your bookshelf. And there is **absolutely no charge** for this invaluable reference book delivered within the United States. A handling charge is required for Handbooks sent overseas. Please call or Fax for information.

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- PC Plug-in Boards for Analog/Digital, Digital/Analog, & Digital I/O
- Connect your PC to Test Instrumentation with IEEE-488, RS-232, RS-422
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For More Information Circle No. 366

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Many manufacturers would require you to use 10.5" of height for a PC, 14" for a monitor, and 3.5" for a keyboard drawer (on which you are supposed to balance the keyboard while you type.) This comes to 28" (16 rack units) of rack height. Our new VRK models include all of these components in just 10.5" (6 rack spaces) tall. You can fit 2⅔ PC's in the space of their system, or simply have a rack-mount PC where it was never possible before.

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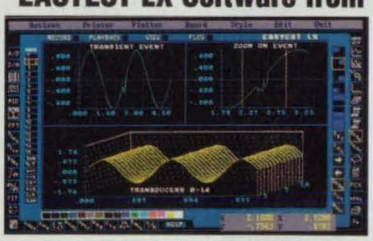

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For More Information Circle No. 366

Effects of Asymmetry of NRZ Data Signals on Performance

Undesired spectral components can degrade performance of a telemetry system.

A report presents a theoretical analysis of the effects of asymmetry in binary non-return-to-zero (NRZ) data signals upon the performance of a radiotelemetry system. Asymmetry can be caused by nonideal rising and falling transitions between the upper and lower binary voltage levels in the transmitter; it can result in the transmission of undesired spectral components that fall within the frequency band of the carrier-tracking loop in the receiver, possibly interfering with tracking. In addition, these undesired spectral components can degrade the bit signal-to-noise ratio.

In the mathematical model of asymmetry used in this analysis, each +1 NRZ symbol is elongated by $\Delta T_s/2$ seconds (relative to its nominal duration of T_s) immediately before a negative-going transition, each −1 NRZ symbol is shortened by $\Delta T_s/2$ immediately before a positive-going transition, and each symbol remains T_s seconds long when no transition occurs. The data signal is assumed to originate in a source that is random in the sense that the signal during each signaling period T_s is independent of signals transmitted during earlier periods.

An equation for the power spectral density is derived from this model. It includes continuous-spectrum, dc-component, and harmonic terms. The equation shows that the spectrum is a function of the probability of occurrence, P, of the +1 symbol; the transition density, P_t (the probability of a transition between +1 and −1 during a symbol period); and $\eta = \frac{\Delta}{2}$, the amount of asymmetry. However, it is also shown that $P_t = 2P(1-P)$, so that the power spectral density can be expressed in terms of P_t and η. The equation is valid for $P_t \leq \frac{1}{2}$.

The equation is used to investigate the effect of the asymmetry on the bandwidth of the signal. Next, the effect of data asymmetry on the performance of the carrier-tracking loop is analyzed. It is shown how to use a set of curves to determine the critical amount of asymmetry beyond which undesired spectral components cause harmful interference to carrier tracking.

A simple mathematical model to predict the overall degradation of the bit signal-to-noise ratio of the telemetry system is derived. It is shown that the degradation increases with the asymmetry.

This work was done by Tien M. Nguyen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Impact of NRZ Data Asymmetry on the Performance of a Space Telemetry System," Circle 61 on the TSP Request Card.*

NPO-18261

Asymmetry in Biphase Data Signals

The effect on carrier-tracking performance is analyzed.

A report presents an analysis of some of the effects of asymmetry in a Manchester (biphase) binary data signal transmitted by phase modulation of a sinusoidal carrier signal. The report extends the analysis described in the preceding article, "Effects of Asymmetry of NRZ Data Signals on Performance" (NPO-18261), to include the case where the data is biphase-modulated directly on a residual carrier.

The analysis is based on the following mathematical models; the transmitted signal is given by

$$S_T(t) = \sqrt{2P}\sin[\omega_c t + m_T d(t)]$$

where t is time, P is the transmitted power, ω_c is the angular carrier frequency, m_T is the modulation index, and $d(t) = \pm 1$ is the Manchester waveform that represents the binary (±1) data sequence. The received signal is corrupted by additive white Gaussian noise $n(t)$ with one-sided noise spectral density N_o. When the data is properly symmetrical, it makes transitions between ±1 at integral multiples of $T_s/2$, where T_s is the symbol period. "Asymmetry" as used in this report denotes a prolongation or shortening of the dwell of $d(t)$ at the +1 or −1 level (while the overall symbol period remains T_s and the signal remains otherwise synchronized with the symbol clock).

These models are described in detail and Fourier-analyzed to obtain equations for the power spectral density of the Manchester data signal $m_T d(t)$ and of the transmitted signal S_T. The asymmetry is found to give rise to undesired spectral components (interference) in the passband of the carrier-tracking loop, and the performance of the loop is characterized by use of the ratio between the interference and carrier powers, I/C. A formula for I/C is given along with a set of curves that can be used to determine the amount of asymmetry that can degrade carrier tracking beyond an acceptable degree.

Next, the contribution of the asymmetry to the phase error in the carrier-tracking loop and the consequent effect upon the probability of error in the Manchester-decoded data are investigated. The probability of error is determined as a function of the asymmetry, the loop signal-to-noise ratio, the loop noise bandwidth, the modulation index, and the signal-to-noise ratio in the bit-rate bandwidth. It is shown that the probability of error increases when the asymmetry, the modulation index, and the product of the loop bandwidth and symbol period increase.

This work was done by Tien M. Nguyen of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Space Telemetry Degradation Due to*

Manchester Data Asymmetry Induced Carrier Tracking Phase Error," Circle 4 on the TSP Request Card.
NPO-18404

Experiment in Aeronautical-Mobile/ Satellite Communication

Performance of a mobile/ satellite communication terminal is evaluated.

A report describes a study of the performance of digital mobile/satellite communication terminals of an advanced design intended for use in ground stations and airplanes in the aeronautical-mobile service. The study was a collaboration of NASA, the Federal Aviation Administration (FAA), the Communications Satellite Corp. (COMSAT), and the International Maritime Satellite System (INMARSAT).

The major part of the study was an experiment that was conducted in two segments during the first several months of 1989. In the first segment of the experiment, a full-duplex, 4,800-bps digital data and voice communication link in a 5-kHz channel was established through the INMARSAT Marecs B2 satellite between the FAA Technical Center in Atlantic City, New Jersey, and the COMSAT Coast Earth Station in Southbury, Connecticut. In the second segment, the same communication link was established between Southbury and a Boeing 727 B100 airplane flying along the east coast of the United States.

During both segments, a series of tests were performed to characterize the performance of the terminals as used in the links. The report describes experimental setup and the results of speech and data tests. Differences between performance computed by theory and numerical simulation based on theory, performance measured in the laboratory, and performance measured in field operation are emphasized and analyzed.

Overall, in both the ground and flight segments of the experiment, a bit-error rate of 10^{-3} was achieved at a bit-energy-to-noise-density ratio (E_b/N_o) of 9.7 dB or less; this equates to a carrier-to-noise ratio (C/N_o) of 46.5 dB-Hz. The worst-case performance of 9.7 dB E_b/N_o, observed during flight tests in the presence of heavy turbulence, was approximately 1.0 dB worse than that measured in the laboratory for additive white Gaussian noise. Much of this degradation was attributed to antenna-pointing errors caused by the turbulence. In more-typical flights in clear weather, an E_b/N_o of 8.9 dB was required to achieve the 10^{-3} bit-error rate. The degradation induced by multipath fading in clear weather was estimated to be 0.3 dB; this was significantly less than the 1.3-dB loss allotted in the aeronautical channel link budgets.

Voice transmissions were digitally encoded at 4.8 kbps and were found to be acceptable, in both quality and intelligibility, to both FAA and NASA personnel. The voice link was demonstrated to be robust under all the flight conditions tested.

This work was reported by Thomas C. Jedrey, Norman E. Lay, and Khaled Dessouky of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "An Aeronautical Mobile Satellite Experiment," Circle 1 on the TSP Request Card. NPO-18288*

Quantitative Evaluation of Teleoperator Performance

The relative merits of alternative control modes are evaluated.

A report describes experiments on remote manual control of a robotic manipulator. The experiments were conducted to evaluate quantitatively the relative effectiveness of several control modes: various combinations of position control, rate control, remote compliance, and feedback from force and torque sensors.

Tasks similar to those done manually by astronauts in extravehicular activity to repair the Solar Max satellite in 1984 were selected for the experiment. The tasks evaluated thus far are removing a thermal blanket, unbolting an electrical panel, and handling bundles of electrical wires and electrical connectors on a simulated Solar Max satellite by means of a remotely controlled robot in a teleoperation laboratory. In one experiment, seven different control modes were applied to the removal and reinsertion of screws on the electrical panel. Data on forces, torques, positions of the robotic end effector, and times needed for the completion of subtasks were recorded and used to analyze and quantify the performances of the human operators.

The data from the experiments showed that in comparison with rate-control modes, position-control modes yielded better overall teleoperation performance and were preferred by operators. Position-error-based force reflection with compliance implemented at the manipulator site was found to be the best control mode. However, the disadvantage of this mode is that the feel of the force-reflecting hand controller is sluggish, and force feedback is slightly delayed because of the limited frequency response of the force-reflection function.

This work was done by Hari Das, Haya Zak, Won S. Kim, Antal K. Bejczy, and Paul S. Schenker of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Performance Experiments with Alternative Advanced Teleoperator Control Modes for a Simulated Solar Maximum Satellite Repair," Circle 29 on the TSP Request Card. NPO-18643*

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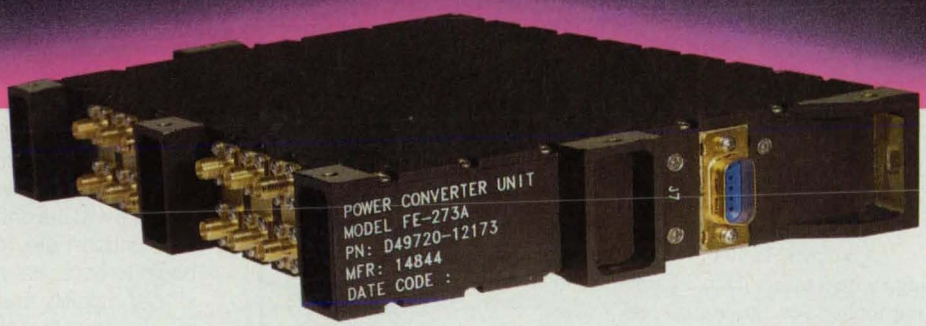

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For More Information Circle No. 608

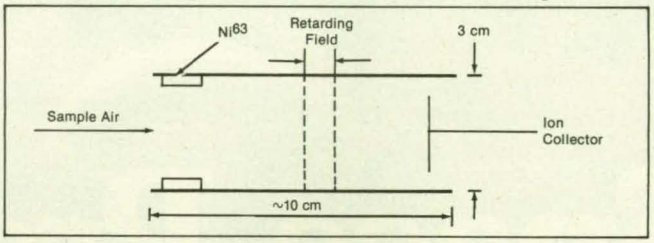
Field-Domain Ion Spectrometry

This technique may lead to development of a portable device to monitor toxic gases.

John F. Kennedy Space Center, Florida

Field-domain ion spectrometry (FDIS) is a variant of the established technique known as ion-mobility spectrometry (originally known as plasma chromatography). Ion-mobility spectrometers are extremely sensitive and can be used to detect low concentration of toxic gases and vapors (such as HCl, HF, and hydrazine) and trace amounts of vapors emitted by hidden explosives and illegal drugs. The new concept of field-domain ion spectrometry offers potential for the development of small, (hand-held), low-power, portable devices that could detect airborne chemical substances in real-time at concentrations at the parts-per-billion level.

The field-domain ion spectometer operates at atmospheric pressure and only requires a small pump to draw an air sample into the instrument. The carrier-gas airstream first enters an ionization region where high-energy electrons from a ^{63}Ni radioactive source ionize the nitrogen molecules in the air. After a series of fast ion–molecule reactions, stable reagent ions (or reactant ions) are produced. The target gas molecules collide and react with the stable reactant ions and become ionized (commonly called product ions). The product ions for each of the target vapors can be distinguished by their unique mobility (speed of drift in the carrier gas divided by the applied electric field), and their concentration determined by the magnitude of the ion signal.



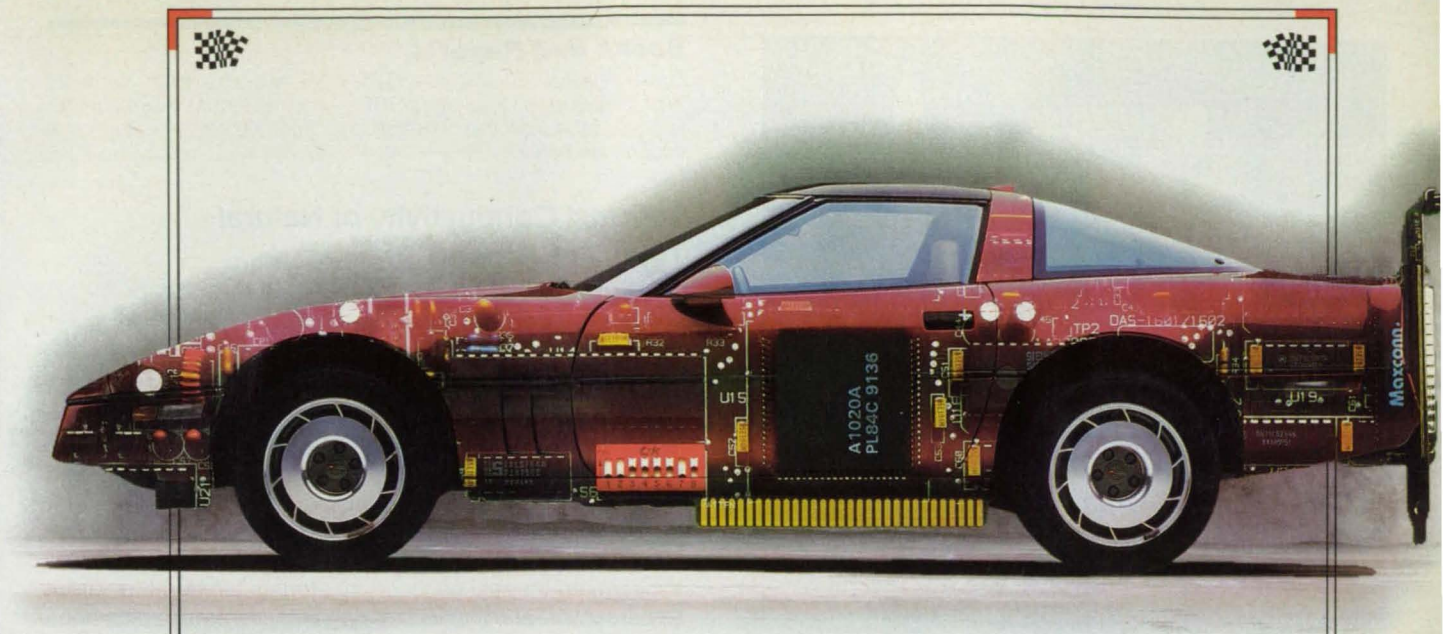
In the **Field-Domain Ion Spectrometer**, the strength of the retarding electric field is varied to distinguish among ions of different mobilities.

Following ionization, the air sample containing neutrals and ions is accelerated to a known velocity and travels into the electric field region. Depending on the magnitude of the electrical field, ions are retarded and do not reach the ion collector plate. Either positive or negative ions can be retarded, depending on the polarity of the electric field. When the retarding strength of the electric field is varied, ions of differing mobilities make their way to the collector and are detected. For a given retarding-field strength, ions with mobilities up to a certain value would pass through the field of the collector; all ions of the same sign with higher mobilities would be rejected and not detected. The resulting mobility spectrum, ion current versus mobility, is a function of the electric-field strength: thus the term "field-domain ion spctrometry."

The continuous ion-separation and detection technique used by FDIS is in contrast to conventional ion-mobility spectrometry (IMS) where a pulse of ions (which contains the reactant and product ions) is gated into a drift region operating at atmospheric pressure. The ion pulse migrates down the drift tube by the influence of a uniform electric field, and the ions begin to separate into distinct packets of similar mobility and are detected. IMS is a pulsed-ion technique, and the mobility spectrum is a function of the ion-drift time (time domain).

The figure is a schematic diagram of a prototype field-domain ion spectrometer. In tests, the prototype apparatus operating at room temperature yielded reproducible field-domain ion spectra of monomethyl hydrazine at (MMH) at concentrations of 100 to 300 parts-per-billion in a nitrogen carrier gas in the presence of ammonia.

This work was done by W. D. Bowers and R. L. Chuan of Femtometrics for **Kennedy Space Center**. *For further information, Circle 90 on the TSP Request Card. KSC-11465*



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For More Information Circle No. 619

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Thermal Conductivity of Natural Type IIa Diamond

The conductivity of a specimen was measured at 500 to 1,250 K.

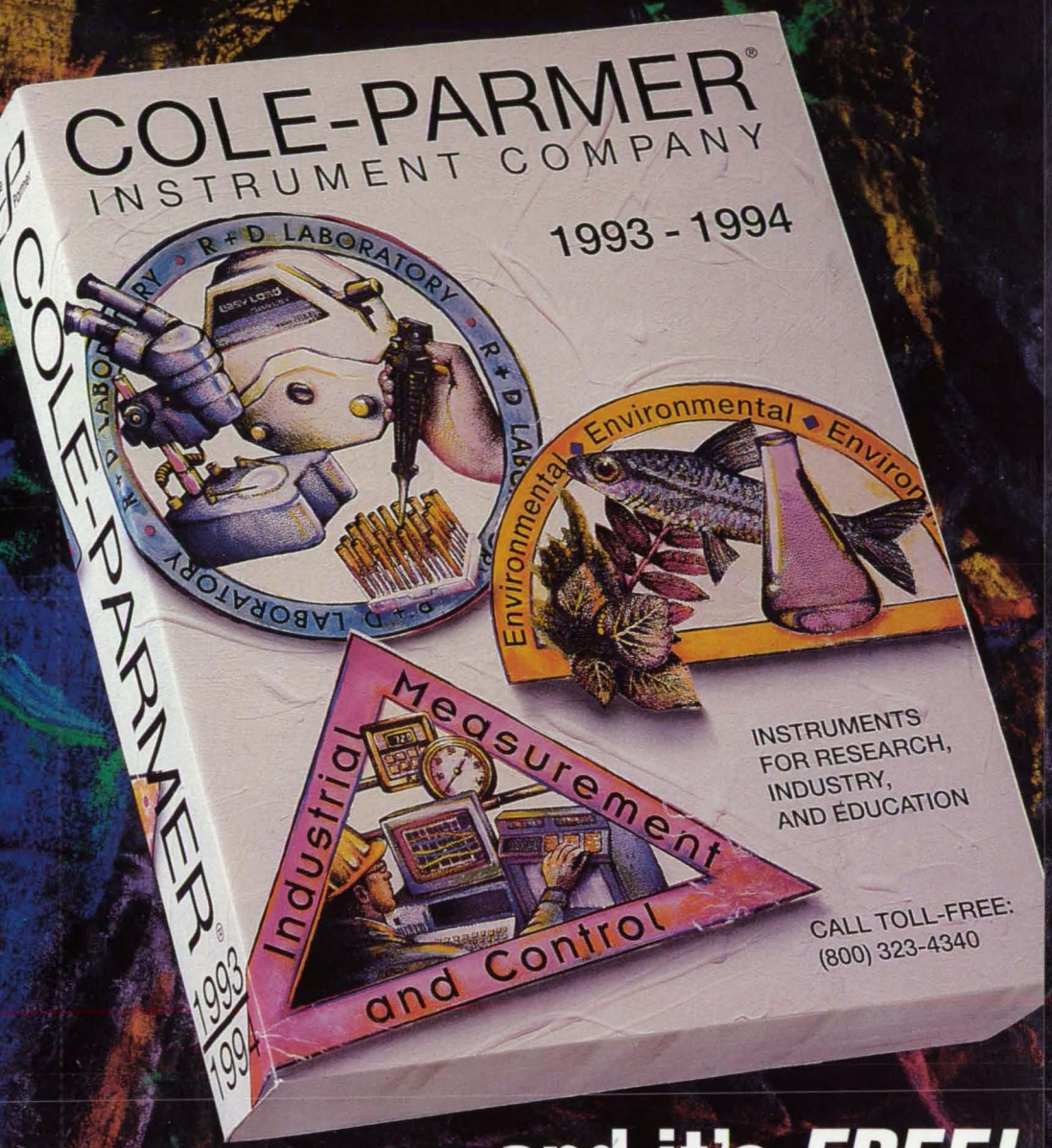
A report describes the application of the flash diffusivity method to measure the thermal conductivity of an 8.04 x 8.84 x 2.35-mm specimen of natural, white, type-IIa diamond at temperatures between 500 and 1,250 K. This is the first time that the thermal conductivity of diamond has been measured at temperatures greater than 450 K. The results, presented graphically, provide a baseline for comparison to recently obtained results on isotopically pure (^{12}C) diamond, which has a measured thermal conductivity at room temperature about 50 percent greater than that of single-crystal type IIa diamonds (the best-heat-conducting type of natural diamond). The results can also be used as a reference against which diamond films produced by chemical-vapor deposition at low pressures can be compared. The high thermal conductivity of diamond can be exploited for a wide variety of applications, and the present results could be used to estimate the heat-conduction performances of diamond films in high-temperature applications.

In the particular implementation of the flash diffusivity method, a xenon flashlamp applied a pulse of heating radiation to one face of the specimen via a sapphire light pipe, while an InSb infrared detector measured the resulting temperature rise of the opposite face of the specimen. The output of the detector was fed through a differential amplifier into a digital storage oscilloscope, which displayed temperature rise versus time.

The sample specimen was coated (sputtered) all over with a layer of tantalum a few micrometers thick, on top of which was sputtered a layer of graphite a few micrometers thick. This combination coating was necessary to obtain adequate absorption of radiation at the surface while preventing the radiation from passing directly through the specimen. The diffusivity was measured both through the specimen along the short dimension (2.35 mm) and through the specimen along the long dimension (8.04 cm). The thermal conductivity was calculated from the diffusivity computed from the measurements, the measured density (3.5 g/cm^3), and the published specific heat.

The resulting data from high temperatures were found to be a reasonable extension of previously published data that were obtained at low temperatures. Although the data from the long-direction and short-direction measurements agreed well between 700 and 1,000 K, the slopes of the logarithm (thermal conductivity)-vs.-logarithm (absolute temperature) curves through the two sets of data points were different: the slope based on the long-direction measurements was 1.13, while that based on the short-direction measurements was 1.54. An extrapolation of the data via the long-direction slope down to 300 K agreed with previously reported data on three type-IIa diamonds, whereas an extrapolation via the short-direction slope agreed well with data on isotopically pure diamond. At the time of the report, the authors were awaiting results of additional measurements at Cornell University to decide whether the "long" or the "short" data are the most accurate.

This work was done by Jan Vandersande, Cronin Vining, and Andrew Zoltan of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Thermal Conductivity of Naural Type IIA Diamond Between 500 K and 1250 K," Circle 5 on the TSP Request Card. NPO-18609*



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For More Information Circle No. 574

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Accurate Inventories of Irrigated Land

A combination of satellite images, aerial photography, and ground surveys yields data for computer analysis.

A system for taking land-use inventories overcomes two problems in estimating the extent of irrigated land: (1) only a small portion of a large state is surveyed in a given year, and (2) aerial photographs made on 1 day out of the year do not provide an adequate picture of areas that grow more than one crop per year. The system, described in a report now available, was developed for the state of California as a guide to controlling, protecting, conserving, and distributing water within the state. It can be adapted to any large area in which large amounts of irrigation water are needed for agriculture.

California's long growing season and varied crop production required the use of Landsat data taken on several different dates so that irrigated land could be identified. The image analyst uses first a summer Landsat image to establish the initial extent of irrigation; the assumption is that if a crop is growing in midsummer in California (or any other semiarid-to-arid area), it must be on irrigated land. Then the analyst uses a late-spring or early-summer image to determine the acreage of such early crops as small grains. Finally, the analyst interprets a fall scene to locate irrigated land that may have been missed previously — especially important in multiple-crop areas.

The analyst also consults agricultural statistics, current farm reports, weather reports, and maps. These information sources aid in interpreting patterns, colors, textures, and shapes on the Landsat-images.

Image interpretation is followed by a ground and aerial photography check to delineate irrigated fields in randomly selected sample areas. The image and ground data are digitized and reduced to proportion data. They are then linked together by regression estimating techniques to compute the amount of irrigated land and the associated errors.

For California, the irrigated acreage is summarized at three levels: 10 hydrologic basins, 58 counties, and statewide. The proportion of land irrigated at least once during the growing season is estimated within ±5 percent relative error 95 percent of the time in each basin and ±3 percent error 99 percent of the time for the entire state. The cost is 1 to 2 cents per agricultural acre per year (1983 prices).

This work was done by S. Wall, R. Thomas, and C. Brown of the University of California, Berkeley for **Ames Research Center**. *To obtain a copy of the report, "Irrigated Lands Assessment for Water Management," Circle 6 on the TSP Request Card.*
ARC-11521

Thermal Conductances of Cold Metal Contacts Below 6 K

Conductances vary with temperature according to a simple power law.

A report presents data on the thermal conductances of pure aluminum and stainless-steel 304 contact pairs. The data cover contacts with surface finishes of 0.1- to 1.6-μm root-mean-square roughness at temperatures from 1.6 to 6.0 K, under applied contact forces up to 670 N. Such data are needed for optimal design of bolted joints in cryogenic instruments, particularly infrared instruments and focal-plane sensors, the performances of which depend on temperature.

The data for both materials and all contact forces and surface finishes fit a simple power law of the form

$$k = \alpha T^n$$

where T is the absolute temperature in K, k is the thermal conductance, and α and n are constants that are determined empirically for each combination of material, force, and finish. Thermal conductances are given in units of mW/K because they are independent of the areas of the facing surfaces in contact and depend on the applied forces rather than on pressures.

The data are plotted in several forms, one being thermal conductance versus temperature for each surface finish, with applied force as a parameter. For aluminum, the greatest conductance (about 17 mW/K) was observed at the smoothest surface finish (0.1 μm), highest temperature (6 K), and highest force (670 N) used in the experiments. For stainless steel 304, the greatest conductance (about 7.5 mW/K) was observed at an intermediate finish of 0.4 μm at the highest temperature (6 K) and highest force (670 N).

The data for aluminum exhibit anomalous behavior in that its thermal conductance is lowest at the 0.4-μm finish, whereas the data for the stainless steel in these experiments as well as previously published data from experiments on brass and copper indicate peak conductances at that finish. A microscopic inspection of the specimens showed no particular surface characteristics that would explain the difference.

This work was done by L. J. Salerno, P. Kittel, and F. E. Scherkenbach of **Ames Research Center** *and A. L. Spivak of Trans-Bay Electronics, Inc. To obtain a copy of the report, "Thermal Conductance of Pressed Aluminum and Stainless Steel Contacts at Liquid Helium Temperatures," Circle 28 on the TSP Request Card.*
ARC-12716

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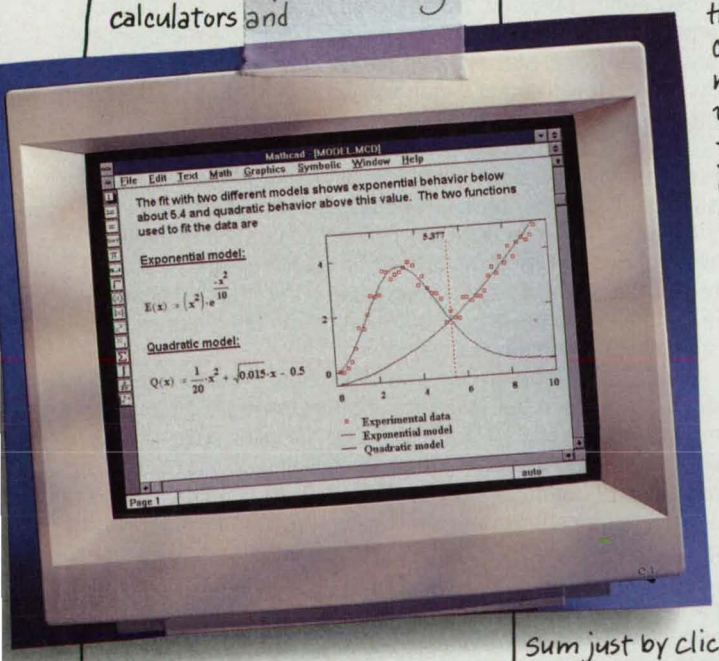

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For More Information Circle No. 421

Materials

Dimensionally Stable Graphite-Fiber/Glass Composites

A process of drawing and coating controls proportions and spacing of the components.

Goddard Space Flight Center, Greenbelt, Maryland

A method of making composites of glass matrices reinforced by graphite fibers provides for control of the proportions, orientations, and distributions of fibers in the matrices and for fused bonds between the fibers and matrices. The method enables the fabrication of composites of high specific strength and dimensional stability. The method is particularly suitable for making low-thermal-expansion platforms for optical instruments.

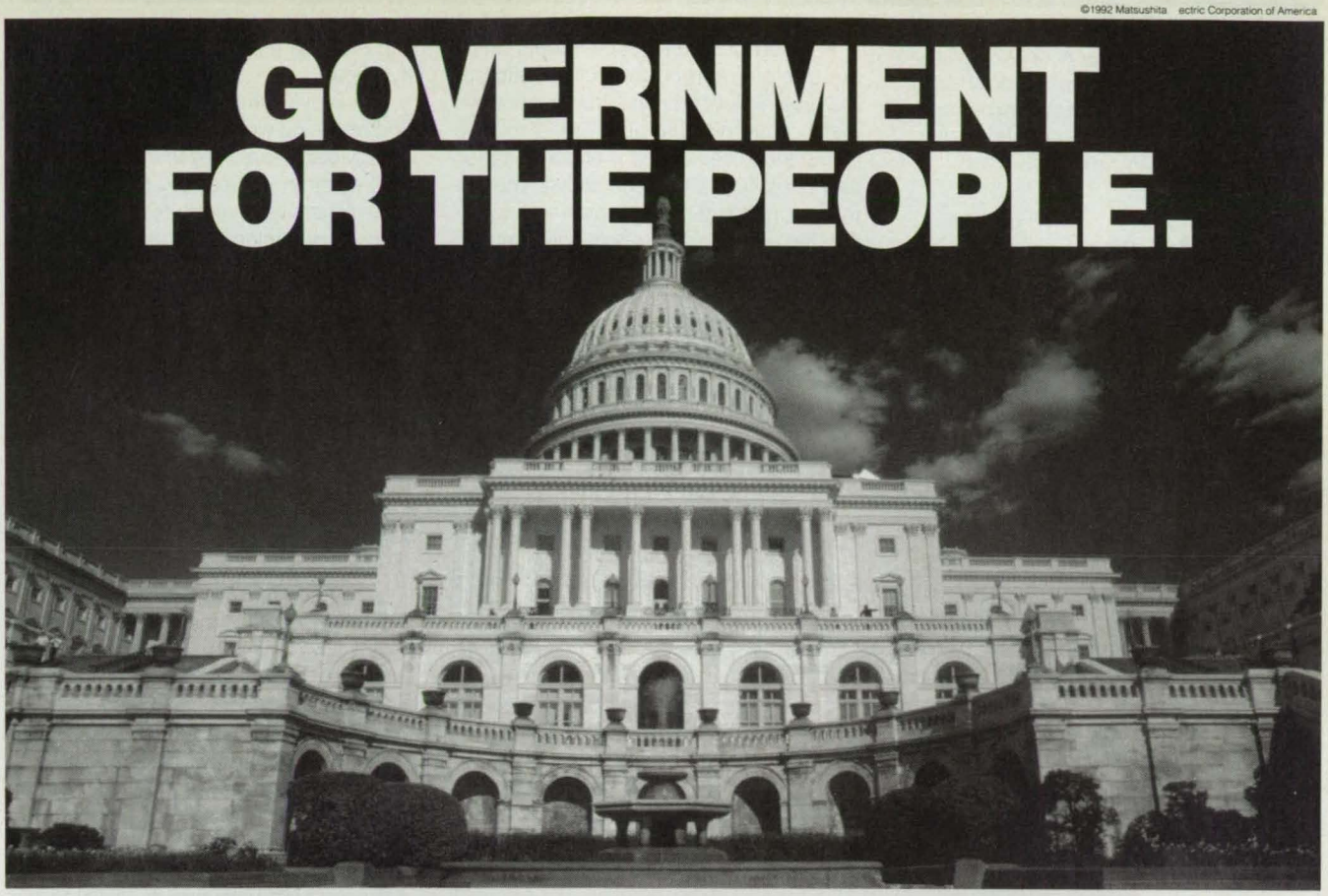
In a typical process according to this method, graphite fiber is pulled up through a molten soda-lime, borosilicate, or other suitable glass in a crucible. The apparatus must be kept in a vacuum or inert atmosphere to prevent oxidation of the fiber. The thickness of the glass coating on the fiber—and hence the relative amounts of glass and graphite in the final composite—is controlled via the temperature of the molten glass and the speed with which the fiber is drawn.

The crucible should be made of platinum, tungsten, molybdenum, or other metal that can withstand the melting temperature [2,400 to 3,000 °F (1,300 to 1,600 °C) in the case of soda-lime glass]. As it leaves the melt, the solidified glass coating is annealed [at a temperature of 950 °F (510 °C) in the case of soda-lime glass] in the inert atmosphere as it emerges from the melt. After cooling, the coated fiber is wound on a spool.

Later, groups of coated fibers can be fused together to form parts of the requisite shape. Selection can be made from a variety of types and compositions of glass and graphite to obtain the desired properties. The glass matrix does not outgas. It serves as a hermetic barrier that prevents moisture from entering the graphite fibers, where it would cause variations in dimensions.

This work was done by Robert Harris, George J. Bergen, and Philip A. Studer of **Goddard Space Flight Center**. *For further information, Circle 86 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13107.



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For More Information Circle No. 491

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Effects of B on Intergranular Hot Cracking in Ni Alloys

Boron increases microfissuring, but carbon mitigates this effect.

A report describes experiments on (1) the role of boron on the solidification of 718-type nickel/chromium/iron superalloys that contain niobium and (2) the relative intergranular segregations of boron, sulfur, and phosphorus in these alloys. The primary purpose of this research was to define the mechanistic role of boron, sulfur, and carbon in the microfissuring of 718-type superalloys. Microfissuring is problematic because it is difficult to detect by inspection, because it compromises fatigue strength by decreasing the crack-initiation time, and because microfissures can act as stress concentrators and as sites for the growth of embrittlement by hydrogen.

Ten alloys were studied by use of light and scanning electron microscopy (SEM), energy-dispersive x-ray analysis, transmission electron microscopy (TEM) with energy-dispersive analysis of thin-film specimens, mechanical tests for susceptibility to microfissuring, differential thermal analysis (DTA), scanning Auger microscopy, and Gleeble thermal analysis (in which each specimen was heated to a peak temperature in 8 s, then quenched in water to "freeze in" its microstructure for metallographic analysis). The results of all of these tests are provided in appendices to the report. The following are among the conclusions drawn from the results:

- Boron increases microfissuring by its potency as a former of Laves phases and by the resultant large range of solidification temperatures that Laves-phase-forming alloys have. The behavior of boron in this respect is similar to that of phosphorus.
- Boron segregates to grain-boundary surfaces in alloys doped with 0.01 weight percent boron. However, the level of segregation is not sufficient to offset solidification effects associated with primary carbide solidification compared to solidification to a Laves eutectic.
- Boron is not unique in its ability to promote microfissuring or in the mechanism through which it promotes microfissuring.
- Carbon, in concentrations greater than 0.1 percent, can significantly alter the solidification behavior and completely reverse the effect of a Laves former like boron. This was observed in a boron alloy with 5.4 weight percent niobium and in a boron/carbon alloy with 4.4 weight percent niobium.
- Sulfur segregates strongly to carbide and eutectic interfaces whether or not it was intentionally added in formulating the alloy. This probably explains why the addition of sulfur did not strongly alter microfissuring behavior.
- Results from Gleeble simulation of the welding heating cycle provided information to verify that results from DTA studies were applicable to microfissuring studies.
- The design of an alloy to minimize microfissuring should consider such compositions as the following: extra-low interstitial compositions, high-carbon compositions, compositions that balance carbide formers against Laves formers, and compositions that can be made free of second-phase precipitates that liquate and that produce liquids that have a large solidification-temperature ranges.

This work was done by Raymond G. Thompson of the University of Alabama at Birmingham for **Marshall Space Flight Center**. *To obtain a copy of the report, "Effects of Boron on Intergranular Hot Cracking in Ni-Cr-Fe Superalloys Containing Nb,"*

Circle 18 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-27252.

Degradation of Fluoropolymers by O(^{3}P)

Factors that affect the degree of oxidation and the rate of etching are discussed.

Three reports describe experimental studies of the degradation of some fluoropolymers (and a few nonfluorinated polymers) by monatomic oxygen in the ^{3}P state. The studies were motivated partly by the need to develop polymeric coats to protect some components of spacecraft against the highly reactive O(^{3}P) atmosphere at typical low Earth orbital altitudes. At the risk of some oversimplification, the results can be summarized as indicating that the fully fluorinated polymers are the most resistant to oxidation, while the cross-linked (but otherwise fully fluorinated) fluoropolymers are the most resistant to etching.

In the experiments described in the first report, thin films of plasma-polymerized tetrafluoroethylene (PPTFE), polytetrafluoroethylene (PTFE), and ion-beam sputter-deposited polytetrafluoroethylene (SPTFE) were exposed to O(^{3}P) downstream of a nonequilibrium radio-frequency O_2 plasma. At a temperature of 22 °C, the rates of etching of PTFE (not cross-linked), SPTFE (somewhat cross-linked), and PPTFE (highly cross-linked) were in the ratio of 8.7:1.8:1.0. A thin, conformal coat of PPTFE was found to protect an underlying reactive polymer, cis-1,4-polybutadiene, against attack by O(^{3}P) until the PPTFE was fully etched away.

From electron spectroscopy for chemical analysis (ESCA), it was determined that PTFE exhibited only minor surface oxidation (uptake of 0.5 atomic percent O) upon etching, and its F/C ratio decreased slightly from the initial value of 2.00 to 1.97. PPTFE exhibited considerable surface oxidation (uptake of 5.9 atomic percent O) and a decrease in F/C ratio from 1.30 to 1.23. SPTFE exhibited a surface oxidation (uptake of 2.2 atomic percent O) intermediate between those of PTFE and PPTFE, with a decrease in F/C ratio from 1.73 to 1.67.

In the experiments described in the second report, ESCA spectra were taken on films of Tedlar [poly(vinyl fluoride)], Kapton F (tetrafluoroethylene-hexafluoropropylene copolymer), and PTFE that had been exposed to O(^{3}P) in orbit or downstream from an O_2 plasma. The results indicated that the perfluorinated polymer structures of PTFE and Kapton F make these films very resistant to oxidation by O(^{3}P), whereas Tedlar, which has three hydrogen atoms and only one fluorine atom in its monomer unit, is highly vulnerable to such oxidation.

The third report presents the results of ESCA measurements of films of poly(vinylidene fluoride)(PVDF), tetrafluoroethylene/ethylene copolymer (TFE/ET) and polyethylene (PE) exposed to O(^{3}P) from an O_2 plasma, and of PE films exposed to O(^{3}P) in orbit. Apart from etching, the films exhibited surface oxidation, which proceeded towards equilibrium saturation oxygen levels. The maximum surface oxygen uptakes from plasma treatment were in the order PE > TFE/ET > PVDF. In view of prior ESCA data on poly(vinyl fluoride) and polytetrafluoroethylene films exposed to O(^{3}P), the extent of surface oxidation is seen to decrease regularly with increase in fluorine substitution in a family of ethylene-type polymers.

This work was done by Theodore Wydeven, Morton A. Golub, and Narcinda R. Lerner of **Ames Research Center** *and Robert D. Cormia of Surface Science Laboratories. To obtain copies of the reports, "Etching of Plasma-Polymerized Tetrafluoroethylene, Polytetrafluoroethylene, and Sputtered Polytetrafluoroethylene Induced by Atomic Oxygen [O(^{3}P)]," "ESCA study of several fluorocarbon polymers exposed to atomic oxygen in low Earth orbit or with-*

in or downstream from a radio-frequency oxygen plasma," and "ESCA study of poly(vinylidene fluoride), tetrafluoroethylene-ethylene copolymer and polyethylene exposed to atomic oxygen," Circle 15 on the TSP Request Card.
ARC-12715

Electrochemical Impedance of Inorganic-Zinc-Coated Steel

Impedance data appear to be correlated with field-exposure corrosion data.

A report describes preliminary experiments to evaluate both direct-current and alternating-current electrochemical impedance measurements as candidate techniques for use in the accelerated corrosion testing of mild-steel panels coated with inorganic zinc-rich primers and exposed to seaside air. The basic idea behind the experiments was to compare electrochemical impedance measurements with anticorrosion performances of coating materials to determine whether the measurements can be used to predict the performances. These experiments were part of a continuing program to identify anticorrosion coating materials that can protect steel panels adequately for as long as 5 years and beyond.

In the experiments, specimen primer-coated steel coupons were immersed in aerated, natural seawater collected from the Atlantic Ocean off Cape Canaveral, Florida. Electrochemical impedances were measured at intervals of about 1 week for about 6 weeks. Direct-current linear polarization resistances and corrosion potentials were also measured periodically.

The collection of materials to be studied included some that had been previously exposed to the beach site and many that were coated with new primers. The primers tested included water-based; solvent-based; and high-solids, low-volatile-organic-conent, solvent-based. Values of polarization resistance were obtained from Nyquist diagrams and from the dc linear polarization data. Capacitances of primer coats were also computed from the ac-impedance data. Analyses of the data show good agreement between the polarization resistances computed from ac and dc measurements. For most of the previously exposed specimens, the results of the electrochemical tests were found to have some correlation with 36-month exposure data.

This work was done by Louis G. MacDowell of **Kennedy Space Center**. *To obtain a copy of the report, "Electrochemical Impedance Spectroscopy for Evaluating Inorganic Zinc Rich Primers on Steel in the STS Launch Environment, Interim Report," Circle 10 on the TSP Request Card.*
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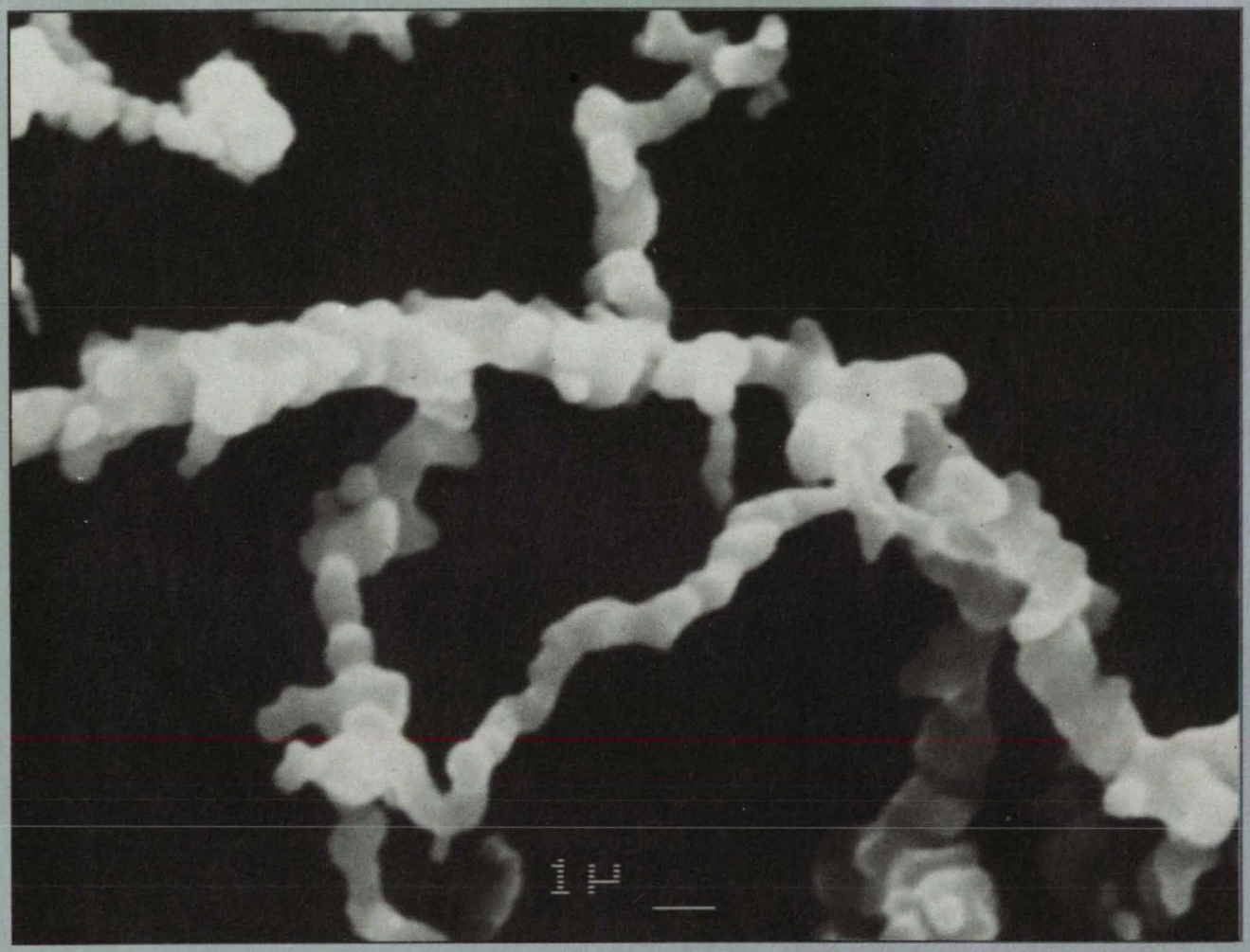

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For More Information Circle No. 652

Computer Programs

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If you don't find a program in this issue that meets your needs, call COSMIC directly for a free review of programs in your area of interest. You can also purchase the annual *COSMIC Software Catalog*, containing descriptions and ordering information for available software.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP Request Card in this issue.

Materials

Computing Reliabilities of Ceramic Components Subject to Fracture

CARES is applicable to a variety of ceramic materials.

The beneficial properties of structural ceramics include high-temperature strength, light weight, hardness, and resistance to corrosion and oxidation. Ceramics intended for use in advanced heat engines have been demonstrated to be able to function at temperatures well above the operational limits of metals. This desirable attribute is offset by the fact that ceramic materials tend to be brittle. When a load is applied to a typical ceramic component, lack of significant plastic deformation causes the component to crack at microscopic flaws, so that the component is destroyed.

CARES calculates the fast-fracture reliability or failure probability of macroscopically isotropic ceramic components. These components may be subjected to complex thermomechanical loadings. The program uses results from a commercial structural-analysis program (MSC/NASTRAN or ANSYS) to evaluate the reliability of a component in the presence of inherent surface- and/or volume-type flaws. The program computes a measure of reliability by use of a finite-element mathematical model that is applicable to multiple materials in the sense that the model can be made a function of statistical characterizations of many ceramic materials. The reliability analysis uses element stress, temperature, area, and volume outputs, which are obtained from two-dimensional shell and three-dimensional solid isoparametric or axisymmetric finite elements.

CARES utilizes the Batdorf mathematical model and the two-parameter Weibull cumulative distribution function to describe the effects of multiaxial stress on the strength of a material. The shear-sensitive Batdorf model requires a mixed-mode fracture criterion and a flaw geometry selected by the user. Flaws that intersect the surface and imperfections embedded in the volume can be modeled. The theory of the total rate of release of strain energy is used to derive a mixed-mode fracture criterion for coplanar extension of cracks. Criteria for the out-of-plane extension of cracks are derived by use of an approximate simple equation with a semiempirical constant that can represent the maximum-tangential-stress theory, the minimum-strain-energy-density criterion, the maximum-strain-energy-release-rate theory, or experimental results. For comparison, Griffith's maximum-tensile-stress theory, the principle of independent action, and the Weibull normal-stress-averaging models are also included.

Weibull material-strength parameters, the Batdorf crack-density coefficient, and other related statistical quantities are estimated from fracture-strength data obtained from four-point-bend bar specimens or uniform-uniaxial-tensile-stress specimens. Parameters for single or multiple failure modes can be estimated by use of the least-squares analysis or the maximum-likelihood method.

CARES is written in FORTRAN 77 and has been implemented on DEC VAX-series computers under VMS and on IBM 370-series computers under VM/CMS. On a VAX, CARES requires 10 Mb of main memory. Five MSC/NASTRAN example problems and two ANSYS example problems are provided. Two versions of CARES are supplied on the distribution tape: CARES1 and CARES2. CARES2 contains subelements, while CARES1 does not. CARES is available on a 9-track, 1,600-bit/in. (630-bit/cm) VAX FILES-11 format magnetic tape (standard medium) or in VAX BACKUP format on a TK50 tape cartridge. The program requires a FORTRAN 77 compiler and about 12 Mb memory. CARES was developed in 1990.

DEC, VAX, and VMS are trademarks of Digital Equipment Corp. IBM 370 is a trademark of International Business Machines. MSC/NASTRAN is a trademark of MacNeal-Schwendler Corp. ANSYS is a trademark of Swanson Analysis Systems, Inc.

This program was written by N. N. Nemeth of Aerospace Design and Fabrication, Inc., and J. P. Gyekenyesi and J. M. Manderscheid of **Lewis Research Center**. *For further information, Circle 26 on the TSP Request Card. LEW-15168*

Mathematics and Information Sciences

C-Language Integrated Production System, Version 5.1

CLIPS 5.1 provides enhancements of rule-based, object-oriented, and procedural programming.

CLIPS, the C Language Integrated Production System, is a computer program that provides a complete environment for the development of expert-system software — programs that are specifically intended to model human expertise or knowledge. CLIPS is designed to enable research on, and the development and delivery of, artificial intelligence on conventional computers. CLIPS 5.1 provides a cohesive software tool for handling a wide variety of knowledge with support for three different programming paradigms: rule-based, object-oriented, and procedural.

Rule-based programming provides for the representation of knowledge by use of heuristics, or "rules-of-thumb," which specify sets of actions to be performed in the given situations. This was the primary paradigm of programming supported by prior versions of CLIPS. Object-oriented programming enables the modeling of complex systems as modular components (which can be easily reused to model other systems or create new components). The procedural programming capabilities provided by CLIPS 5.1 enable CLIPS to represent knowledge in ways similar to those allowed in such languages as C, Pascal, Ada, and LISP. Working with CLIPS 5.1, one can develop expert-system software by use of rule-based programming only, object-oriented programming only, procedural programming only, or combinations of the three.

Originally, the primary method of representation in CLIPS was a forward-chaining-rule language based on the Rete algorithm. The term "Production System" represented in the CLIPS acronym alludes to this rule-based paradigm of programming. It in-

cludes three basic elements: a fact list containing data that represent the current state of the "world," a knowledge base of "if–then" rules, and an inference engine. The "if" portion of a rule is a series of patterns (conditions) that specify the facts (data) that cause the rule to be applicable. The "then" portion of a rule is the set of actions to be executed when the rule is applicable. The facts and rules together are called productions, and the collection of conditions and actions to be taken are constructed into a rule network called a production system. Using the Rete algorithm, the inference engine matches patterns against facts to determine which rules should be executed and when.

Version 5.1 of CLIPS includes extensive enhancements of this rule-based paradigm of programming. A feature called "Incremental Reset" allows rules to "see" facts that are entered before or after the rules. Seven strategies for the resolution of conflicts are supported for rule-activation salience values. These strategies are called "Depth," "Breadth," "LEX" (lexicographic), "MEA" (means–end analysis), "Complexity," "Simplicity," and "Random." There is also a feature to maintain truth by internally tagging those facts that are logically dependent on others. If certain facts are retracted, CLIPS automatically retracts the logically dependent facts.

Object-oriented programming (OOP) combines aspects of both data-abstraction and procedural knowledge. This paradigm of programming allows data and procedures to be closely coupled within objects — the procedures for manipulating the data pertaining to an object are parts of the object. The CLIPS object-oriented language, COOL, is a hybrid of features from many different OOP systems as well as new ideas. Features supported by COOL include classes with multiple inheritance, abstraction, encapsulation, polymorphism, dynamic binding, and message-passing with message-handlers. The first five features in this list are the five primary features that an OOP must possess.

In prior versions, the only procedural programming supported by CLIPS was the definition, by the user, of external functions. These functions, which are still supported, are defined in an external language, such as C, and are called from within CLIPS. Before functions of this type can be called from within CLIPS, however, CLIPS has to be recompiled and relinked with them. In contrast, CLIPS 5.1 allows programmers to define new functions within CLIPS without having to recompile and relink CLIPS. These functions are known as deffunctions. Generic functions are similar to deffunctions in that they can be used to define new procedural code directly in CLIPS, and they can be called like any other function. However, generic functions are much more powerful because they can be overloaded in a manner similar to that of operator overloading in such languages as Ada and C++. COOL also overlaps procedural programming to a certain degree because message-handlers are pieces of procedural code that implement specified behaviors for particular classes of objects in response to particular messages.

CLIPS 5.1 includes an integrated MicroEMACS editor and an on-line help facility. Both integer and double-precision data are supported, and global variables can be defined and used. CLIPS 5.1 also maintains a "constructs-to-c" function, which can be used to create multiple run-time modules (each of which includes the user's choice of rules and other constructs). Switching between different images created by use of the construct-to-c function is also supported. The CRSV (Cross-Reference, Style, and Verification) utility is still available to aid in development, debugging, and verification of large rule bases; however, it has not been extended to support all new features of CLIPS 5.1.

COSMIC offers four distribution versions of CLIPS 5.1. Executable files, source code, utilities, and examples are included on the program medium. All distribution versions include identical source code for the command-line version of CLIPS 5.1. This source code should be compilable on any computer with an ANSI C compiler. Each distribution version of CLIPS 5.1 except the Mac-

intosh version includes an executable code for the command-line version. For the UNIX version of CLIPS 5.1, the executable code for the command-line interface version is for Sun4 computers running SunOS 4.1.1, and the Makefile may have to be modified slightly to be used on other UNIX computers.

Each of the UNIX, Macintosh, and MS-DOS versions of CLIPS 5.1 includes a computer-specific interface. For the MS-DOS version of CLIPS 5.1, the window interface is distributed in executable form only; however, ordering information for the source code for the interface is provided in the documentation. Source code, a Makefile, and an executable code for the Macintosh interface version of CLIPS 5.1 are provided only on the Macintosh distribution diskettes. Likewise, for the UNIX version of CLIPS 5.1, only source code and a Makefile for an X-windows interface are provided. The X-window interface requires X11/Release 4, and the Makefile for this interface has been tested only on Sun4 computers running SunOS 4.1.1. The VAX version of CLIPS 5.1 comes only with the generic command-line interface.

The executable code provided with the PC distribution was built with Borland's ANSI C compiler with VROOM overlays (included in their Turbo C++ v1.01 and Borland C++ v2.0 and v3.0 products) to enable the inclusion of all the program features and still allow enough memory to build application programs within 640 K. Because of the overlays, the executable code of this distribution runs very slowly on 808x and 80286-based computers without expanded or extended memory, but an executable code built without overlays does not run at all on such computers unless compiler flags are set to deactivate one or more of the features of CLIPS (e.g., rules, COOL, deftemplates, deffunctions, the editor, the help system). Large application programs require an 80286 or better central processing unit, a DOS extender, and a CLIPS executable code that has been recompiled by use of the facilities of the DOS extender.

The version of CLIPS 5.1 for IBM PC-compatible computers requires DOS v3.3 or later, and is distributed in compressed form on a set of six 5.25-in. (13.34-cm), 360K diskettes in MS-DOS format. A hard disk is required. The Macintosh version is distributed in compressed form on two 3.5-in. (8.89-cm), 800K diskettes in Macintosh format, and requires System 6.0.5 and 1 Mb of random-access memory. The version for DEC VAX/VMS computers is available in VAX BACKUP format on a 1,600-bit/in. (630-bit/cm) 9-track magnetic tape (standard distribution medium), or a TK50 tape cartridge. The UNIX version is distributed on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format.

The CLIPS 5.1 documentation includes a two-volume user's manual and a three-volume reference manual consisting of basic and advanced programming guides and a utilities & interfaces guide. An architecture manual is available separately. The documentation is available in printed form or on two Macintosh disks in Microsoft Word 4.0 format. Please inquire of COSMIC to obtain pricing and ordering information for either the architecture manual or the electronic version of the documentation. CLIPS was developed in 1986 and Version 5.1 was released in 1991.

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This program was written by Gary Riley, Brian Donnell, Huyen-Anh Vu Ly, Chris Culbert, and Robert T. Savely of **Johnson Space Center**; *Daniel J. McCoy of the University of Houston; and Joseph Giarratano of the University of Houston/Barrios Technology. For further information, Circle 106 on the TSP Request Card.*
MSC-22078

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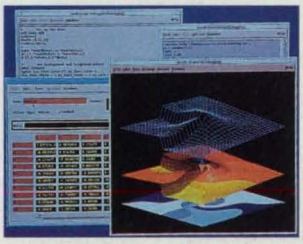

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For More Information Circle No. 567

Streamwise Upwind, Moving-Grid Flow Algorithm

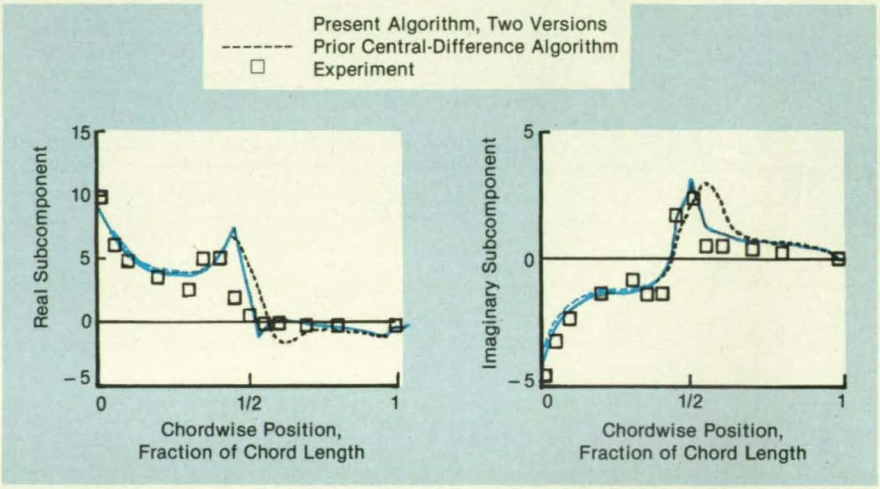
Extension to moving grids enables computation of transonic flows about moving bodies.

Ames Research Center, Moffett Field, California

This algorithm computes unsteady transonic flow on the basis of the nondimensionalized thin-layer Navier–Stokes equations in conservation-law form. It solves the equations by use of a computational grid based on curvilinear coordinates that conform to, and move with, the surface(s) of the solid body or bodies in the flow field. Consequently, it can simulate such complicated phenomena as transonic flow (including shock waves) about an oscillating wing.

The present algorithm was developed by extending a prior streamwise upwind algorithm that solves the equations on a fixed curvilinear grid. That algorithm was described in "Streamwise Algorithm for Simulation of Flow" (ARC-12718), *NASA Tech Briefs*, Vol. 15, No. 7, July 1991, page 70. To recapitulate: the coordinate system is temporarily rotated locally to align one of its axes with the streamwise direction. For differencing, in the streamwise direction, of the terms that represent convection, flux vectors are split in such a way that the local flux-vector bias is switched between one value if the flow is locally supersonic and another value if it is locally subsonic. The formulas for differencing in the rotated coordinate system are then transformed back to the original coordinate grid, where the numerical solution is computed.

The present algorithm accounts for the motion of the grid by incorporating a transformation of all velocities into the moving coordinate system. The inviscid fluxes are evaluated by use of a finite-volume numerical-integration scheme, with quantities defined at the centers of the cells of the computational grid. The viscous fluxes are evaluated by use of a second-order central-difference scheme.



The Real and Imaginary Subcomponents of the first Fourier component of the coefficient of pressure on the upper surface at the half-span station of an oscillating wing were computed and measured. The values computed by the two versions of the present algorithm agree more closely with the measured values in the vicinity of the motion of the shock than do the values computed by the central-difference algorithm.

Two different versions of the algorithm were tested in computations of unsteady transonic flow over an oscillating wing. One version performs a time-marching computation via the lower-upper-factored, alternating-direction-implicit (LU-ADI) method, which is accurate to first order but temporally nonconservative. The other version implements a conservative implicit method. The solutions were found to be insensitive to the time conservativeness of the implicit version when practically small time steps were used, and the temporally nonconservative version was found to be more numerically stable and computationally efficient. Comparisons with data from experiments indicate that the present upwind algorithm captures the motion of shocks better than does the prior central-difference algorithm (see figure).

This work was done by Peter M. Goorjian and Guru P. Guruswamy of **Ames Research Center** *and Shigeru Obayashi of MCAT Institute. Further information may be found in NASA TM-102800 [N90-21739], "Extension of a Streamwise Upwind Algorithm to a Moving Grid System."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-13109

Ultrasonic Detection of Transverse Cracks in Composites

The conventional C scan is modified to generate oblique shear waves.

Lewis Research Center, Cleveland, Ohio

The conventional ultrasonic C scan that is used to detect flaws in graphite/epoxy composite panels can be modified to enhance sensitivity to transverse (in the sense of through-the-thickness) cracks. The modification involves reorientation and repositioning of the ultrasonic transmitter and receiver to take advantage of mode-conversion phenomena at the interfaces between the liquid couplant and the panel to be probed. Although the mode-conversion equations that must be solved to take full advantage of the technique are somewhat complicated, they are straightforward, and the technique is implemented easily in practice.

Figure 1 shows the configuration for probing a typical flat composite panel, in which the fibers lie parallel to the surface, albeit at oblique angles with respect to the edges. In the conventional ultrasonic C scan, the sound passes as a longitudinal (compression) wave through the panel directly through the thickness; that is, perpendicularly to the surface. The conventional C scan is particularly effective in detecting interply delaminations, which are parallel to the surface, but it is relatively ineffective in detecting through-the-thickness cracks.

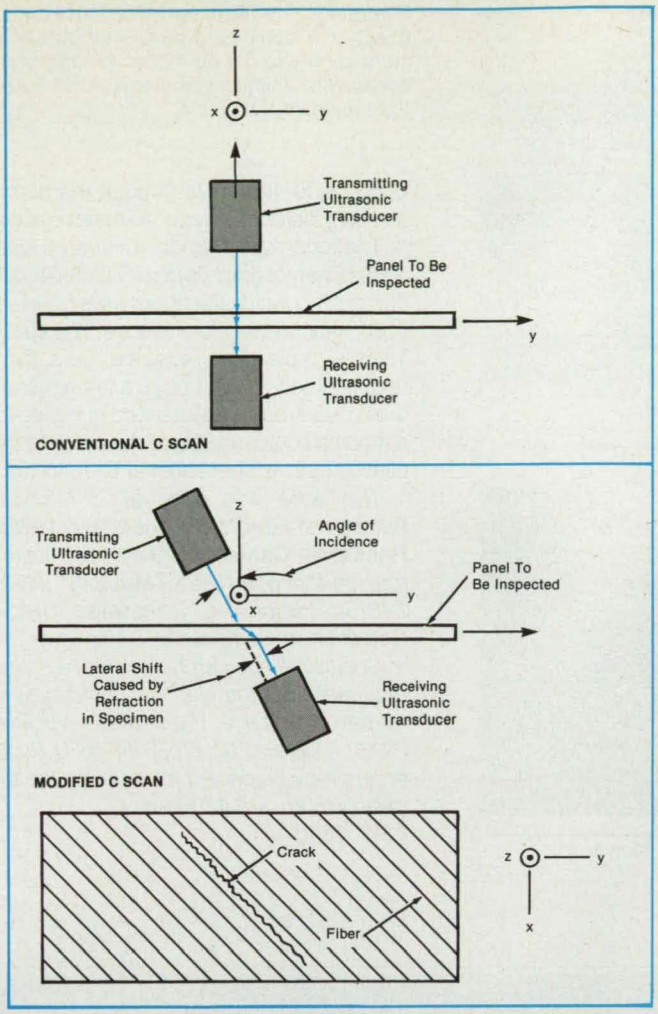
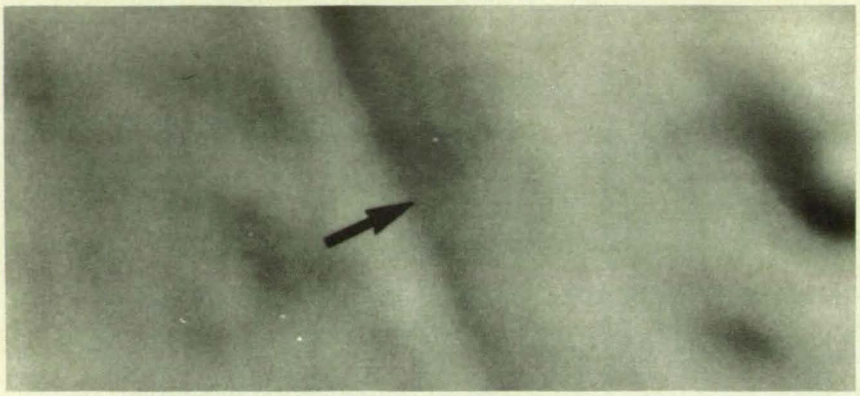


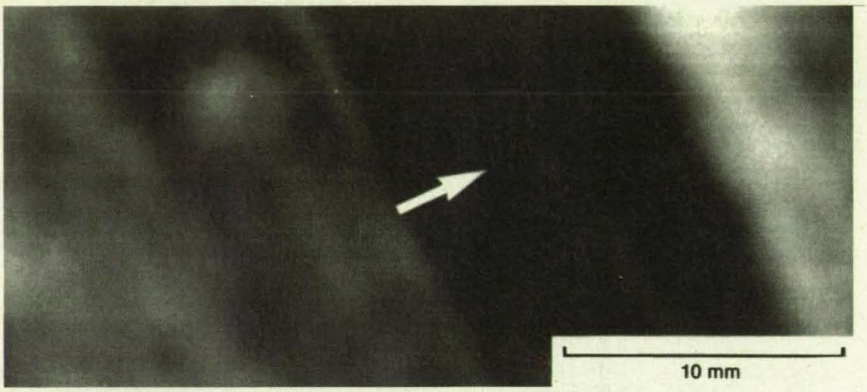
Figure 1. The **Conventional and Modified C Scans** differ in the orientations and positions of the transducers. In the modified C scan, the angle of incidence is chosen so that only shear waves propagate obliquely through the panel.

The modified C-scan technique is based on the hypothesis that oblique shear waves may be affected more strongly by such cracks. Oblique shear waves can be generated by mode conversion: When a plane acoustic wave in the liquid (which is a simple longitudinal or compression wave) strikes the surface of the laminate or another solid, three refracted waves can be produced in the solid: a longitudinal wave (called the "primary compressional," or "*P*," wave), an oblique shear wave with displacement perpendicular to the surface (called the *"SV"* wave), and a shear wave with displacement parallel to the surface (called the *"SH"* wave).

The relationships among the amplitudes, speeds, and directions of propagation of these waves depend on the anisotropic properties of the composite, the angle of incidence, and the orientation of the plane of incidence. Snell's law of refraction still applies but is embedded in the mode-conversion equations that express these relationships. The equations can be solved to find a critical angle of incidence beyond which the *P* wave is reflected away from the panel, but the *SV* and/or *SH* waves



CONVENTIONAL (NORMAL-COMPRESSION-WAVE) C SCAN



MODIFIED (OBLIQUE-SHEAR-WAVE) C SCAN

Figure 2. The **Through-the-Thickness Crack** in a composite panel can be seen more clearly in the ultrasonic C scan produced with oblique shear waves. The arrows indicate the crack.

continue to propagate through the panel and can, therefore, be used to detect cracks.

The technique was demonstrated with a specimen of graphite/epoxy laminate 1.1 mm thick in which the fibers were oriented at 60° with respect to one edge. The specimen was split in two along the fibers, then reassembled, to synthesize a through-the-thickness crack. As illustrated in Figure 2, a modified C scan showed the crack more clearly than a conventional C scan did.

This work was done by J. Michael Pereira and Edward R. Generazio of **Lewis Research Center**. *Further information may be found in NASA TM-103261 [N90-27815], "Improved Transverse Crack Detection in Composites."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15340

Nozzle/Diffuser for Test Section of Wind Tunnel

The fan consumes less power, and flow is distributed better in the test section.

Langley Research Center, Hampton, Virginia

The nozzle/diffuser is a short tapered (expanding-flow) duct that distributes the flow more nearly evenly over a slightly wider path in an open test section of a closed-circuit wind tunnel. The nozzle/diffuser has a rectangular or circular cross section like that of the contraction duct just upstream of the test section and is, in effect, an extension of the contraction duct (see Figure 1).

The nozzle/diffuser is used in conjunction with a collector, which is a similar short separate duct tapered in the opposite sense to channel and accelerate the flow into a downstream expansion duct called the "first diffuser." The nozzle/diffuser increases the recovery of pressure in the first diffuser; that is, the increase in the pressure by virtue of having higher diffuser exit pressure on the way to the fan. Because the flow returning to the fan is at a higher pressure, less fan power is needed to maintain the same rate of flow.

To operate efficiently, the nozzle/diffuser must have a gentle taper—no more than a few degrees (see Figure 2). this

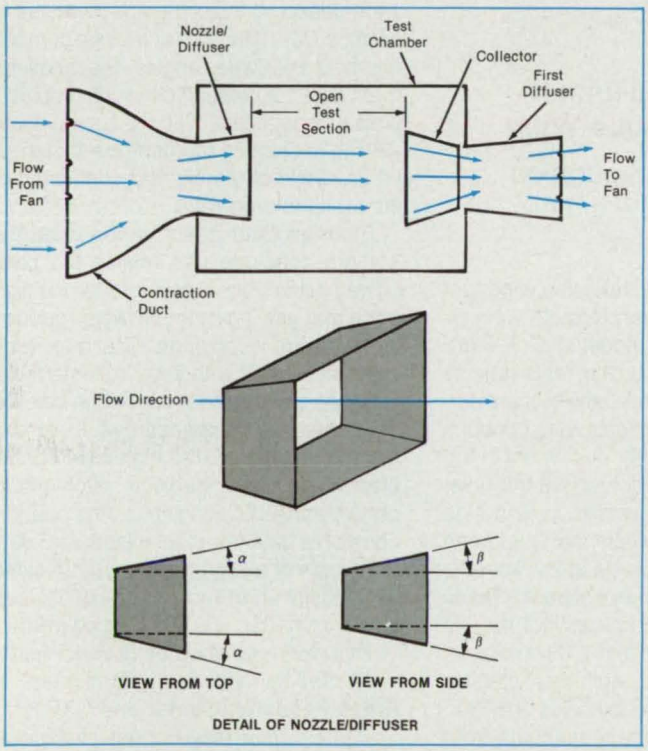


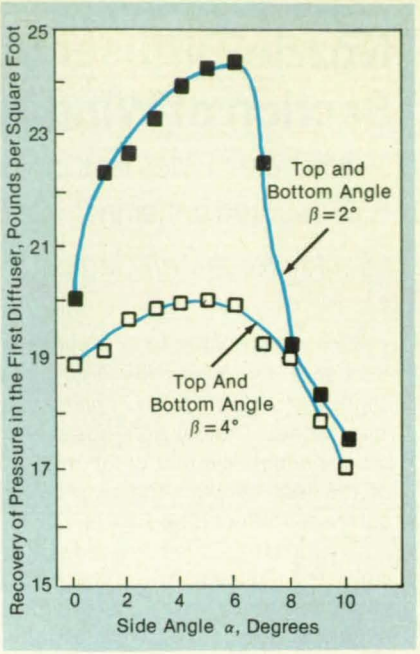
Figure 1. The **Nozzle/Diffuser** improves the distribution of flow in the test section and increases the recovery of pressure in the first diffuser.

Figure 2. The **Recovery of Pressure** in a scale-model wind tunnel was measured with various taper angles α and β (as defined in Figure 1). Of those combinations tested, the one that yielded the greatest recovery of pressure was $\alpha = 6°, \beta = 2°$.

taper causes the flow to diffuse slightly, with a consequent slight decrease in the speed and the desired increases in the width and degree of uniformity of the flow. The acceleration of flow along the collector into the first diffuser at the downstream end of the test section favorably affects the distribution of velocity at the inlet to the first diffuser, effectively reducing the blockage and resulting in the increase in the recovery of pressure.

This work was done by P. Stephen Barna for **Langley Research Center**. *For further information, Circle 14 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14424.



Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Transonic Wind-Tunnel Test of an Oblique Wing

A high-pivot configuration did not confer the anticipated advantages.

A report describes transonic wind-tunnel tests of an oblique, pivotable wing fitted to a 0.087-scale model of an F-8 airplane. The purpose of the tests was to study performance and stability characteristics. In particular, the tests were conducted to determine whether placement of the pivot at a higher position above the fuselage than previously results in less side force and yawing moment than had been observed in previous tests at low speeds.

The wing, designed by contractor Rockwell International, had an aspect ratio of 10.3, a straight taper, and a thickness-to-chord ratio of 0.14. Longitudinal-stability data were taken at sweep angles of 0°, 30°, 45°, 60°, and 65°, at mach numbers from 0.25 to 1.40. Reynolds numbers varied from 3.2×10^6/ft to 6.6×10^6/ft (10.5×10^6/m to 21.7×10^6/m). Angles of attack ranged from −5° to +18°. Most data were taken at zero sideslip, but a few tests were conducted at sideslip angles of ±5°.

The primary emphasis of the tests was upon the pitching and yawing characteristics of the higher- and lower-pivot configurations at transonic and low supersonic speeds. Secondarily, tests were conducted at low speeds to determine behavior when the wing was clean and when landing flaps were deflected. Also, the effectiveness of ailerons was measured at a range of mach numbers and sweep angles. The measurement data are presented in such graphical plots as coefficient of lift vs. coefficient of yawing or pitching moment, coefficient of lift vs. angle of attack, and coefficient of lift vs. lift-to-drag ratio.

From an examination of the data, the authors conclude that raising the pivot proved detrimental overall, though the side force and yawing moment were reduced under some conditions. The maximum coefficient of lift with flaps deflected was less than anticipated in the design calculations. Also, in comparison with the low-pivot configuration, the high-pivot configuration was less stable in pitch under certain transonic conditions. An appendix compares data from these tests with data from tests of a slightly more complicated wing designed at Ames that exhibits better performance and handling properties.

This work was done by R. A. Kennelly, J. M. Strong, and R. L. Carmichael of **Ames Research Center** *and I. M. Kroo of Stanford University. Further information may be found in NASA TM-102230 [N89-29725], "Transonic Wind Tunnel Test of a 14% Thick Oblique Wing."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12812

Elastic and Plastic Deformations in Butt Welds

The uses of linear and nonlinear mathematical models are described.

A report presents a study of the mathematical modeling of stresses and strains, reaching beyond the limits of elasticity, in bars and plates. The study is oriented toward the development of the capability to predict stresses and the resulting elastic and plastic strains in butt welds. The exploration of this subject matter was prompted by failures, at apparent stresses and strains lower than the ultimate stresses and strains predicted by a linearized model, of butt welds in 2219-T87 aluminum aft skirts that support the Space Shuttle prior to launch. However, this study has wider significance in that high-performance structures in general are likely to be stressed into the regime of inelasticity, and therefore the capability to model inelasticity accurately is essential to adequate ultimate-safety-factor analyses of such structures.

The report contains eight chapters. Chapter I is a brief introduction that explains the purposes of the study. Chapter II introduces the general topic of the mathematical modeling of stresses and strains in solid materials, beginning with a description of the elastic and plastic regimes in the stress-vs.-strain behavior of a simple uniaxial tensile-test specimen of a polycrystalline (and therefore isotropic) material. This chapter goes on to discuss the variation of Poisson's ratio with strain, strain-energy-based criteria for failure in three-dimensional stress fields, development of the equations of inelastic triaxial stress vs. strain from the Hooke's-law equations of elastic stress vs. strain, the two-parameter power-law representation of inelastic shear stress vs. strain, and the onset and modeling of orthotropy in an isotropic material stressed beyond the limit of elasticity.

Chapter III focuses on a technique of analytical modeling in which nonlinear stresses and strains in bars and plates are related to each other by power-law approximations and synthesized with conventional linear strength-of-materials equations. The resulting representation is similar to a piecewise-linear representation; it simplifies the algebra and enables continuous integration.

Chapter IV discusses the application of analytical and finite-element numerical models to bar and plate specimens. The results of these computations are compared in an assessment of the relative applicability and accuracy of the models. Chapter V discusses stresses in butt welds, taking account of the effects of discontinuities between plate and weld filler

materials and of geometric effects. Chapter VI discusses the analysis of data supplied by strain gauges in the nonlinear stress-vs.-strain regime. Strain-gauge data are important in the verification of mathematical models, which is discussed briefly in chapter VII. Chapter VIII summarizes the findings of the study.

This work was done by V. Verderaime of **Marshall Space Flight Center**. *Further information may be found in NASA TP-3075 [N91-16413], "Plate and Butt-Weld Stresses Beyond Elastic Limit, Material and Structural Modeling."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
MFS-28605

Single-Cycle versus Multicycle Proof Testing

The choice depends largely on shape and material.

A report compares single-cycle with multiple-cycle mechanical-stress tests of parts under mechanical stresses. Although nondestructive testing (NDT) is generally preferred for detecting cracks, there are occasions when proof testing is useful as a supplement, the report notes. A case in point is that of a part so geometrically complex that NDT techniques do not provide complete information. The objective of proof testing is to screen out gross manufacturing or material deficiencies and thereby provide additional assurance of quality.

Fracture-mechanics analysis should be used to determine whether proof testing is appropriate and, if so, how many cycles are needed. In typical proof tests, loads of about 1.2 times the operating loads are applied, and these test loads may inflict undetectable damage on the components through subcritical crack growth or stable tearing.

If a component under test is made of a brittle material, there is little or no crack growth. Only one load cycle is needed, and the fracture-mechanics analysis is straightforward. On the other hand, tough materials often show significant stable crack growth on loading. Multiple load cycles are appropriate, and the fracture-mechanics analysis is considerably more complex.

The report is based on a study in which an analytical model of multicycle proof testing was developed and used to reveal the interaction of key variables: the distribution of crack sizes, the character of the material resistance curve of the material in question, and elastic/plastic loading conditions. Experiments were performed on specimens of a nickel alloy to explore the nature of crack growth in the material and obtain data for the model. In addition, information on the distribution of crack sizes in parts made of the alloy was compiled and statistically analyzed.

The report concludes that, among other things, changes in the distribution of crack sizes during multicycle proof testing depend on the initial distribution, the number of cycles, the relationship between the resistance of the material and the elastic/plastic fracture-mechanics parameter, the relationship between load control and displacement control, and the magnitude of the applied load or displacement. Whether single-cycle or multicycle testing should be used thus depends on the shape, material, and technique of fabrication of the components to be tested.

This work was done by S. J. Hudak, Jr., R. C. McClung, M. L. Bartlett, and J. H. FitzGerald of Southwest Research Institute and D. A. Russell of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "A Comparison of Single-Cycle Versus Multiple-Cycle Proof Testing Strategies," Circle 64 on the TSP Request Card.*
MFS-27255

Machinery

Basalt-Block Heat-Storage Plant

The proposed storage medium is readily available.

Lyndon B. Johnson Space Center, Houston, Texas

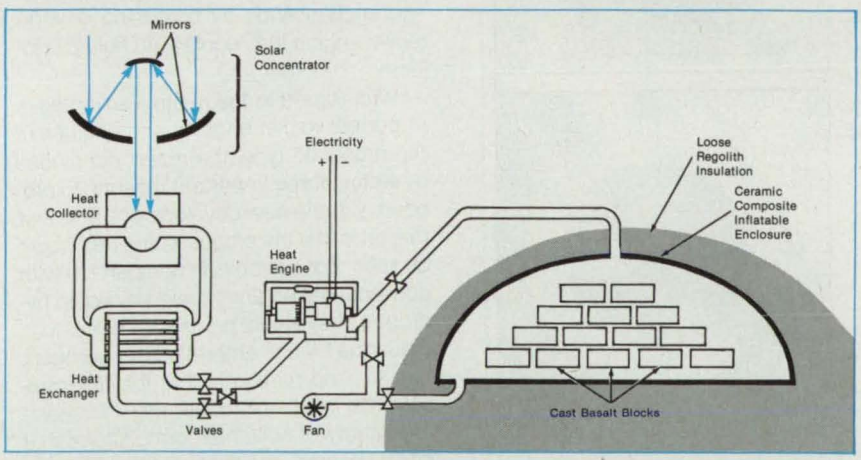
A concept for the storage of solar heat for later use is based on the use of basalt, the plentiful igneous surface rock of the Earth, Moon, and possibly other bodies in the solar system. According to the concept, basalt would be cast into blocks and stacked in an inflatable gas-tight enclosure that would serve as the heat-storage chamber.

During the day, a large solar concentrator would collect heat from the Sun (see figure). A heat exchanger would transfer the heat to a circulating gas that would, in turn, deliver some of the heat to a heat engine to produce electricity. The gas would also flow around and between the basalt blocks, transferring some of the heat to them. (The blocks would be stacked loosely to leave channels between them to allow the gas to flow.) At night, valves would close to exclude the heat collector and heat exchanger from the circuit. The flowing gas would then absorb heat from the blocks and deliver it to the heat engine.

The cast basalt blocks would be similar to the cast basalt plates now produced commercially for use as abrasion- and chemical-resistant tiles. The blocks would be made by essentially the same process of consolidation by heat — either radiant heat or heat generated in the raw material by microwaves. The heat from the solar concentrator could even be used to form the blocks on site.

The construction of the heat-storage plant would begin with the laying out of a ceramic composite fabric that would later serve as the enclosure. After the blocks have been stacked on the fabric, the edges of the fabric would be pulled together over the blocks and sealed, forming the enclosure. The enclosure would then be covered with a berm of regolith (essentially, loose soil and rock from the site) insulation.

This work was done by Thomas A. Sullivan of **Johnson Space Center**. *For further information, Circle 108 on the TSP Request Card.*
MSC-21803



Blocks Would Be Enclosed in a gas-tight bag under a berm of soil. Heat would flow to the blocks from a solar collector during the day and from the blocks to the heat engine at night.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Fluidized-Solid-Fuel Injection Process

An alternative rocket-engine concept is proposed.

A report proposes the development of rocket engines that would burn small grains of solid fuel entrained in gas streams. The report is as entertaining as it is informative: it is replete with historical anecdotes and references to prior developments in rocket propulsion technology, and it incorporates relevant knowledge from disciplines as diverse as zoology, paleontology, thermodynamics, and techniques of fabrication (to mention a few).

To feed a typical engine of the proposed type, the grains of fuel would be drawn from a fluidized-bed hopper by a stream of gas, which would be injected into the combustion chamber of the engine. The application to rocket propulsion would be new, but the concept of fluidized-solid-fuel injection is not new: it has been the basis of stationary plants that burn sawdust and pulverized coal.

The main technical discussion in the report is divided into three parts. Part I discusses established fluidization technology, selected aspects of conventional solid-fuel rockets, and some basic principles that govern the operation of rocket engines. Part II starts by discussing the variety of rockets and rocket engines (mostly military) used by nations around the world, then turns to specific aspects of the designs of antiship missiles. Then it describes a ramjet engine in which the combustion of the fuel is sustained by the increase in temperature behind compression shocks, and discusses the problems involved in burning fluidized injected solid fuel in such an engine.

Part III presents the rocket-engine equation. It discusses the significance of the specific impulse and the ratio between the initial and final masses of the rocket; these are parameters in the rocket-engine equation and are principal figures of merit of a rocket engine. The relative merits of various rocket-engine designs are analyzed from the perspective of the need to maximize one or the other of these parameters. The section ends by proposing a large rocket engine that would burn fluidized injected solid fuel.

With regard to the relative advantages of current rocket engines and engines of the proposed type, the report concludes by stating three important reasons to proceed with the new development: The first reason is that the proposed engines would be safer. For example, in comparison with conventional engines fueled by liquid hydrogen, they would present no risk of loss of turbine blades embrittled by hydrogen. The second reason is that the fluidized-solid-fuel injection process might increase the variety of solid-fuel formulations that could be used. The third reason is that the development of the fluidized-solid-fuel injection process would provide a base of engineering knowledge from which one could develop still other chemical and/or nuclear processes.

This work was done by William Taylor of Lockheed Space Operations Co. for **Kennedy Space Center**. *To obtain a copy of the report, "Fluidized Fuel Process," Circle 38 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11412.

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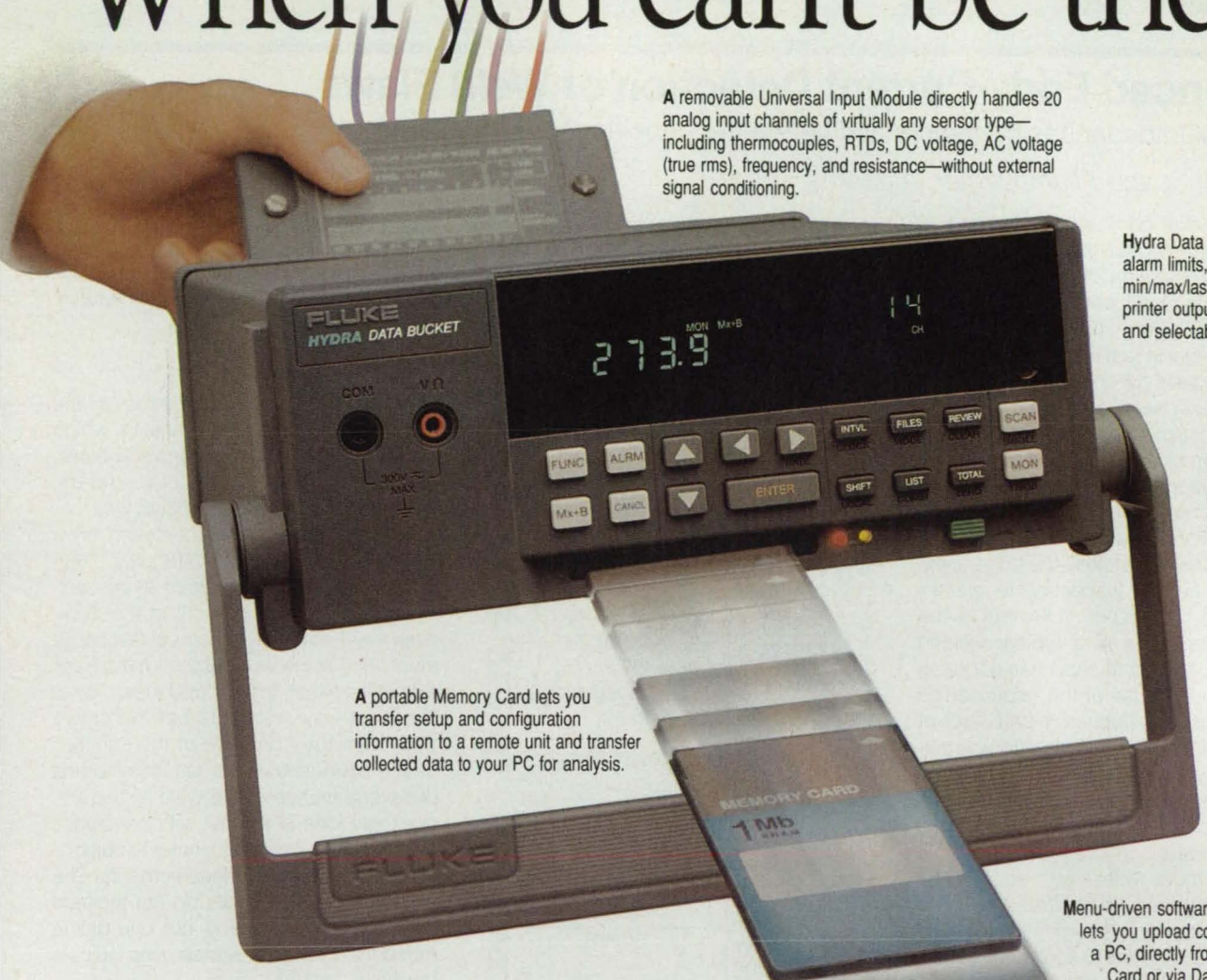

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Enhanced Eddy-Current Detection of Weld Flaws

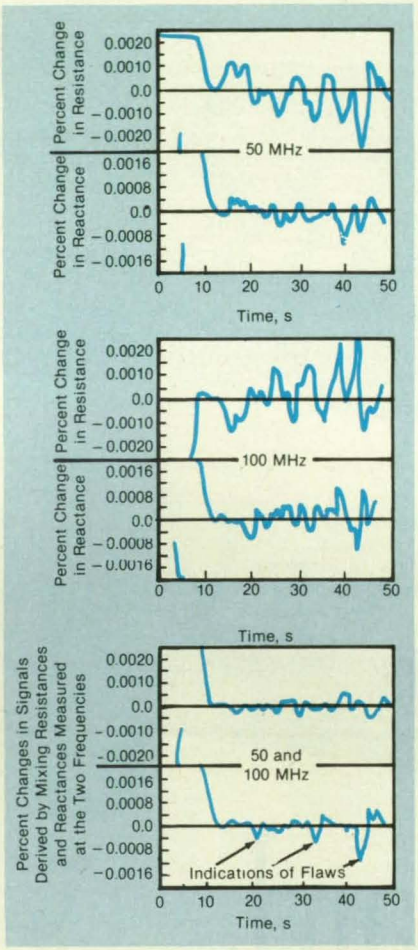
Mixing of impedances measured at different frequencies reduces noise and helps reveal flaws.

Marshall Space Flight Center, Alabama

A method of computer processing of eddy-current inspection signals can enhance the detection of flaws in robotic welds in thin metal walls. The method is intended to make it possible to inspect each weld joint in real time while the parts being joined are still on the welding stage. Typically, such welds are too thin for ultrasonic inspection, and one cannot gain access to both sides of the workpiece to inspect it radiographically.

Eddy-current inspection is often performed to find flaws near the surfaces of metallic parts. Heretofore, the effort to extend eddy-current inspection to greater depths [up to 0.060 in. (1.5 mm)] in the heat-affected zone in a typical welded metal (e.g., Inco* 718 alloy) has not been successful because of the relationships among sensitivity, frequency, and depth of penetration: The approximately conical portion of the workpiece effectively penetrated by the electromagnetic field of the eddy-current probe is deeper and wider (and, therefore, the electromagnetic energy is dispersed more widely, with consequent lower sensitivity) at lower frequencies. At higher frequencies, the eddy-current system is more sensitive to such surface features as irregularities in the crown of the weld, which features can give rise to noise.

In the new method, one excites the eddy-current probe simultaneously at two different frequencies; usually, one of which is an integral multiple of the other. The resistive and reactive components of impedance of the eddy-current probe are measured at the two frequencies, mixed in a computer, and displayed in real time on the video terminal of the computer. This mixing of measurements obtained at two different frequencies often "cleans up" the displayed signal in situations in which band-pass filtering alone cannot: the mixing removes most of the noise, and the displayed signal resolves flaws well.



These Eddy-Current-Inspection Signals show the benefit of mixing measurements, taken at two different frequencies. Distance scanned along the weld is related to time on these plots.

The method was demonstrated on a weld in a sheet of Inco* 718 alloy 0.060 in. (1.5 mm) thick. Notches of 30 percent, 40 percent, and 50 percent of the thickness were made by electrical-discharge machining of the weld joint from the back side of the sheet, to simulate hidden flaws. The weld was scanned from the crown side (from the front side of the sheet).

The figure shows the results of scans of several inches of the weld at two frequencies (one at a time) with band-pass filtering and at both frequencies simultaneously with mixing of measurements. The single-frequency signals do not indicate any of the flaws clearly, but one of the mixed two-frequency signals does indicate the flaws clearly.

*"Inco" is a registered trademark of the Inco family of companies.

This work was done by Lisa M. Van Wyk and James D. Willenberg of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 35 on the TSP Request Card.*
MFS-29816

Speed-Selector Guard for Machine Tool

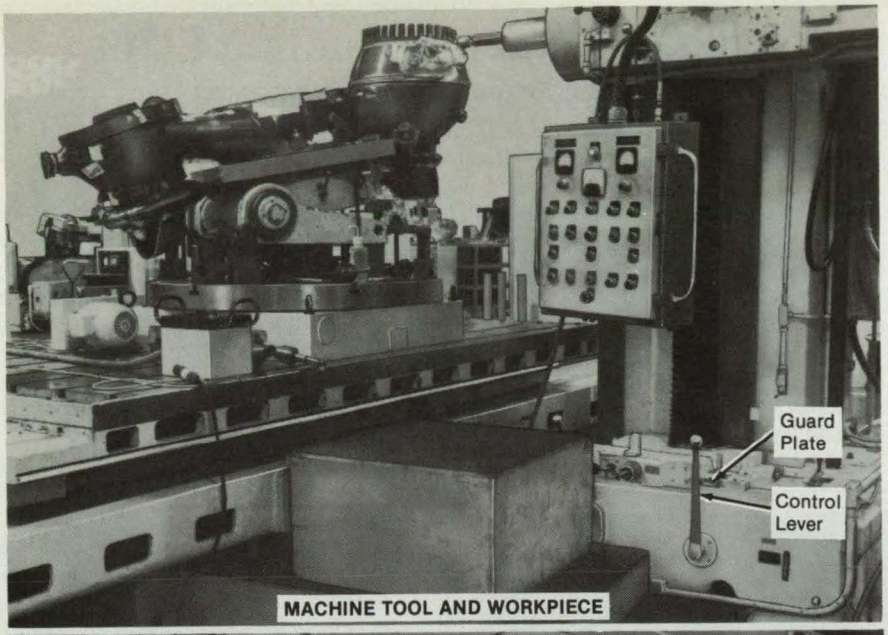
A sliding plate prevents accidental resetting of a control lever.

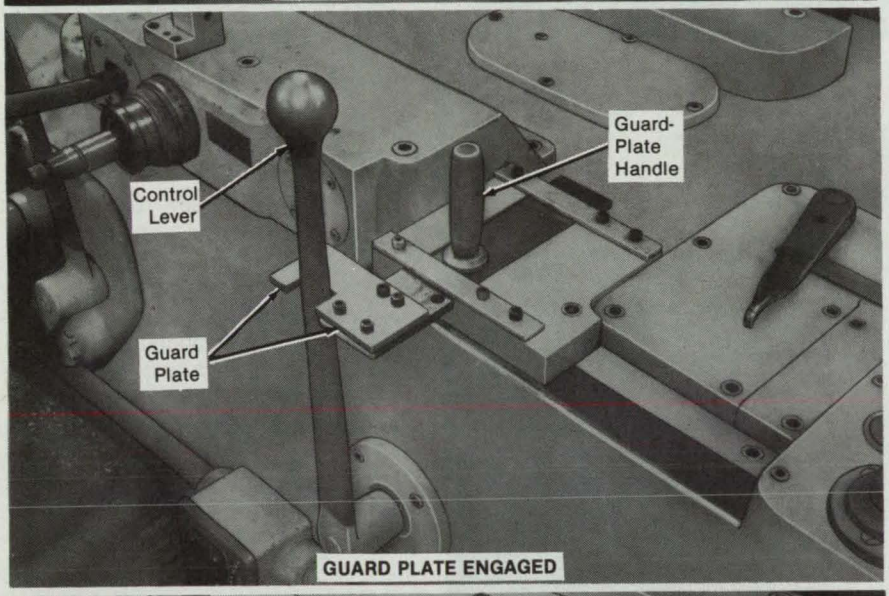
Marshall Space Flight Center, Alabama

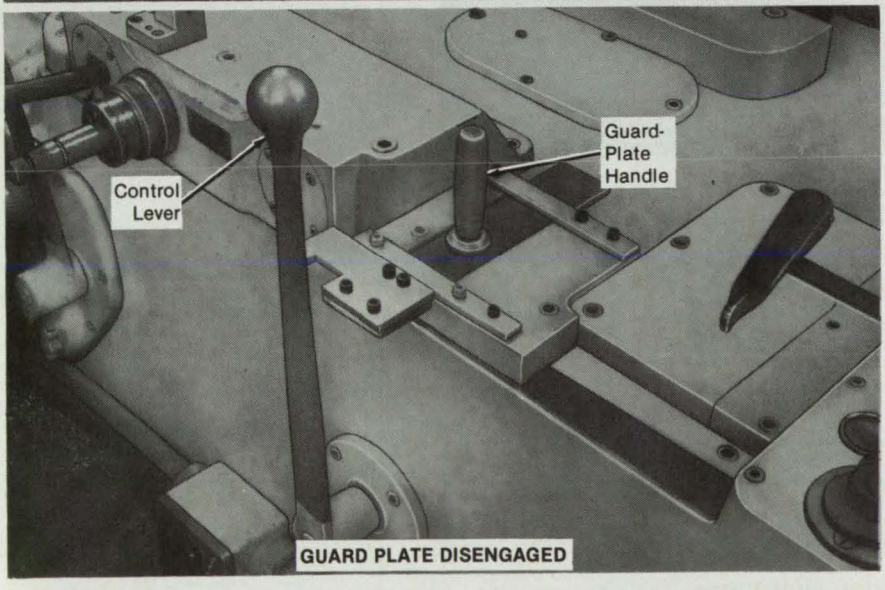
A simple guardplate prevents an accidental reversal of direction of rotation or a sudden change of speed of a lathe, milling machine, or other machine tool. The guard thus protects personnel from the injury and equipment from the damage that could occur if a speed- or direction-control lever were inadvertently placed in the wrong position.

The guard plate is custom-made for the specific machine and control settings. For example, it could consist of a small notched plate bolted to a sliding bar on the frame of the machine tool (see figure). In this case, the notch is constructed so that it engages the control lever only at its proper speed and direction setting; the guard blocks other settings. To release the control lever for other settings, the operator simply slides the mounting bar and guardplate away from the control lever.

This work was done by Roda J. Shakhshir and Richard L. Valentine of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29520







A **Simple Notched Plate** allows the control lever to be placed at only one setting. The operator uses the handle to slide the guard to engage or disengage the control lever.

Growth and Patterning of High-T_c Superconducting Films

Photolithographic processes do not lower the superconducting-transition temperature.

Lewis Research Center, Cleveland, Ohio

Superconducting films of $YBa_2Cu_3O_{7-x}$, which have high superconducting-transition temperatures (T_c's), have been deposited on $LaAlO_3$ substrates and etched into patterns representative of passive microwave devices, with no deterioration of the superconducting properties. One such pattern was a ring resonator designed to operate at 35 GHz.

Each film was deposited on a substrate by laser ablation in an atmosphere of flowing oxygen at a pressure of 170 mtorr (23 Pa). A laser beam of 248-nm wavelength scanned a $YBa_2Cu_3O_{7-x}$ target, generating a plasma that impinged on the substrate, coating the substrate with a film of composition similar to that of the target (see figure). The substrate was kept at a temperature of 775 °C. After deposition, the pressure of the oxygen was raised to 1 atm (0.1 MPa), and the substrate was then cooled slowly to room temperature.

Each pattern, with lines 10 to 20 μm wide, was formed in a superconducting film by standard photolithography and wet etching. The procedure included the following steps:

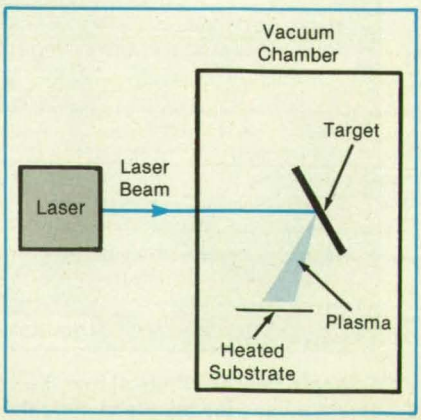
1. Application of a negative photoresist;
2. Soft baking of the photoresist at 90 °C for 1 h;
3. Photographic exposure of the photoresist;
4. Exposure to photoresist developer and rinse;
5. Etching for 500 s in ethanol containing 1 percent molar bromine; and
6. Removal of the photoresist by a commercial stripper at 70 °C.

Finally, silver contacts were evaporated onto each patterned film and annealed at 500 °C for 1 h.

There was no discernible change in the T_c of each film once it was deposited; that is, in each case, the T_c remained constant throughout the patterning process, even after exposure to the processing chemicals and high temperatures.

This work was done by J. D. Warner, K. B. Bhasin, N. C. Varaljay, and D. Y. Bohman of **Lewis Research Center** *and C. M. Chorey of Sverdrup Technology, Inc. Further information may be found in NASA TM-102436 [N90-22421], "Growth and Patterning of Laser Ablated Superconducting $YBa_2Cu_3O_7$ Films on $LaAlO_3$ Substrates."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-15106



The Laser Beam Ablates a Target, depositing the superconductive ablated material on a heated substrate.

Toroid Joining Gun for Fittings and Couplings

A hand-held gun is used to join metal heat-to-shrink couplings.

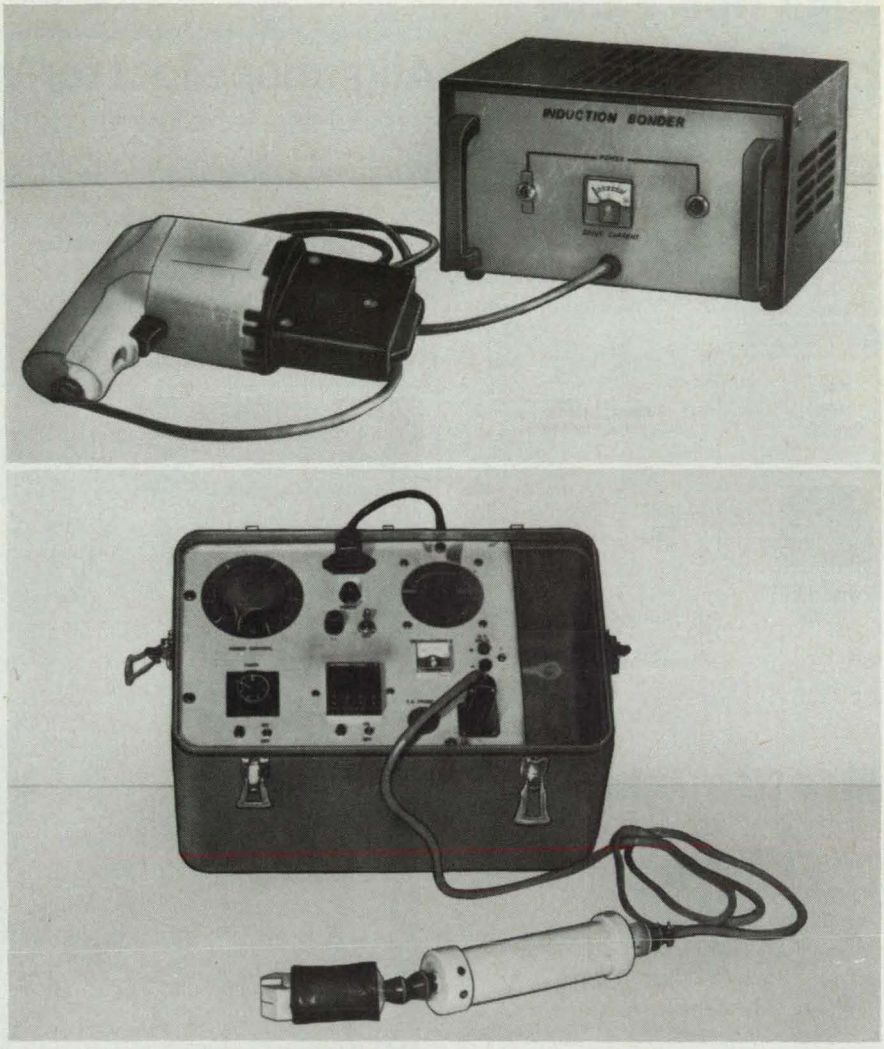
Langley Research Center, Hampton, Virginia

The U.S. Air Force is currently using metal heat-to-shrink couplings and fittings for flight-line, depot, and battlefield repair of hydraulic tubes in military aircraft. NASA is also considering these couplings and fittings for use in the fabrication of large structures in outer space. The use of such couplings and fittings requires a rapid-heating device that is lightweight, portable, and easy to use. It must be nonhazardous for use around aircraft fuel and reliable under all environmental conditions.

Accordingly, a hand-held gun for heating metal heat-to-shrink couplings has been developed. It uses magnetic induction (eddy currents) to produce heat in a metal coupling, and a thermocouple to measure temperature and thus signal the end of the process. The gun, called the "toroid joining gun" (see figure), can concentrate high levels of heat in localized areas. The gun can be reconfigured for use on metal heat-to-shrink fitting and coupling applications.

The gun includes a tank circuit, a ferrite toroidal core into which a gap has been cut, a low-power source, and a temperature controller. The gun is positioned so that the coupling or fitting to be heated lies in the gap in the core. The inductive coil of the tank circuit encircles the toroidal core. When the source is energized, a current passes through the coil, generating a magnetic flux that is conveyed through the core to the metal coupling in the gap. The resulting eddy currents in the coupling generate sufficient heat to shrink it. The power source is then automatically de-energized by the temperature controller.

This induction heating device provides rapid heating, operates on low power, and is lightweight and portable. It is safe for use around aircraft fuel and has no detrimental effects on surrounding surfaces or objects. It is reliable in any environment and under all weather conditions. This gun is a logical device for taking full advantage of the capabilities of the new metal heat-to-shrink couplings and fittings.



The **Lightweight, Hand-Held Toroid Joining Gun** is reconfigured for use on metal heat-to-shrink fittings and couplings.

This work was done by Robert L. Fox, Robert J. Swaim, Samuel D. Johnson, and John D. Buckley of **Langley Research Center** *and Carl E. Copeland, Robert H. Coultrip, David F. Johnston, and William M. Phillips of Inductron. For further information, Circle 95 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14278.

Rapid Prototyping of Layered Composite Parts

Numerically controlled cutting would accelerate fabrication of layers.

Marshall Space Flight Center, Alabama

Prototype parts that consist of layers of composite material ("composite" in the sense of fiber/matrix; e.g., Kevlar® polyester/epoxy) would be made rapidly according to a proposed method. The proposed method is derived from stereoscopic lithography, which can be used to build weaker layered plastic models of composite parts, but not to build working models in the stronger composite materials.

In the proposed method, the CATIA or CAEDS computer program would be used to generate a three-dimensional mathematical model of the prototype part. In the model, the geometry of the part would be specified in layers, as in stereoscopic lithography. The model data for each layer would be fed to a computer-numerically-controlled ultrasonic cutting machine. A sheet of prepreg (uncured composite material) of the specified layer thickness would be placed in the machine and cut, under control of the model data, to the specified shape of that layer.

The cut prepreg sheets would be stacked automatically in sequence to build up the prototype part to the required shape and size. Prior to curing, metallic bore sleeves, bushings, and other inserts could be add-

ed. If the prepreg layers were made in "2 ½-dimensional" weaves, then the cured composite part would have some additional integrity along the through-the-thickness axis.

This work was done by Edwin D. Wolff of Rockwell International Corp. for **Marshall Space Flight Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29870.

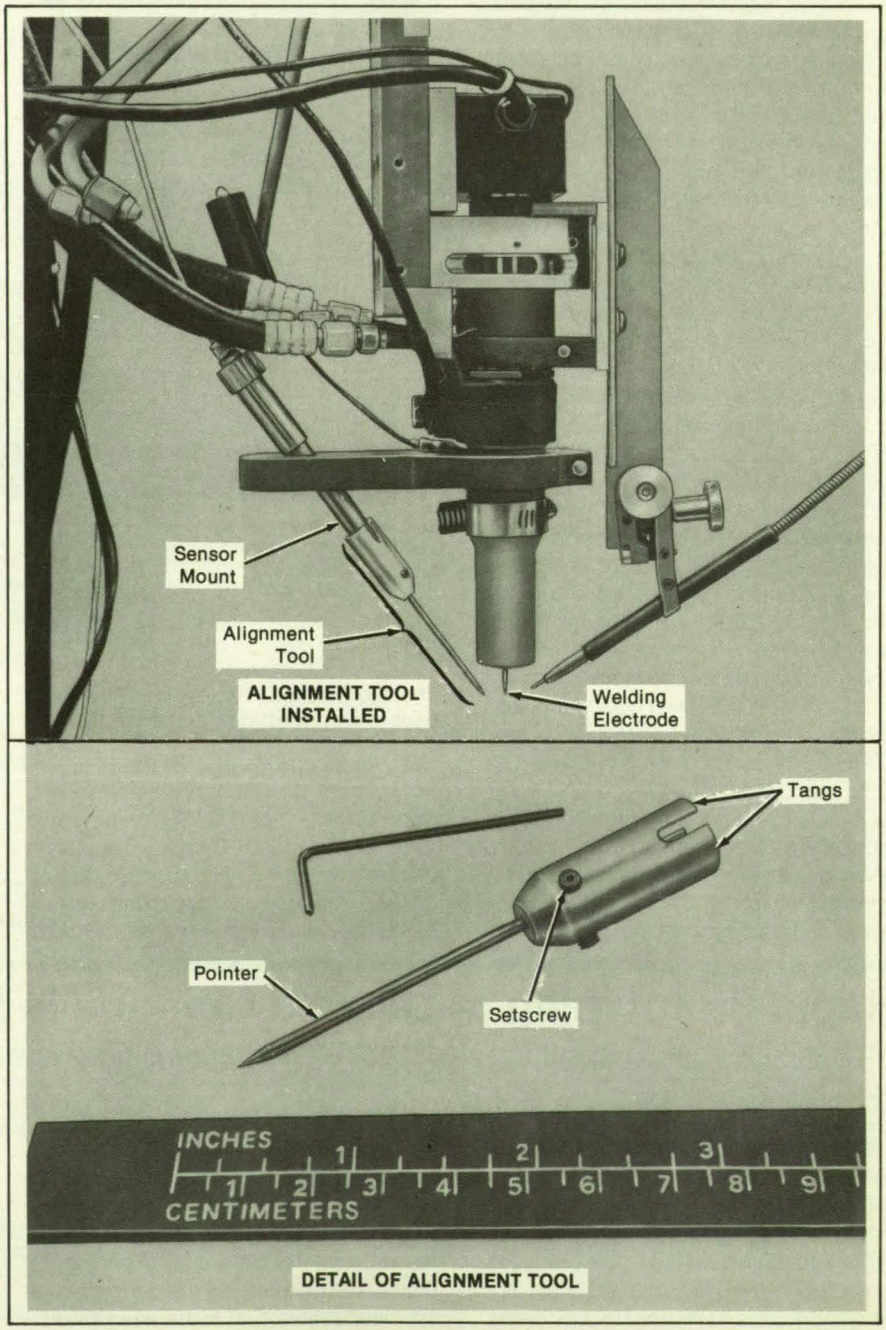
Alignment Tool for Welding Sensor

The tool enables alignment of the sensor for maximum response.

Marshall Space Flight Center, Alabama

An alignment tool enables the accurate positioning of an optoelectronic sensor that measures weld penetration. The tool, designed for use on a tungsten/inert-gas welding apparatus, is used to adjust the position of the sensor so that its photodiode puts out the maximum signal.

The alignment tool includes a slotted cap with a pointer (see figure). The tangs are bent in slightly to provide a snug slip fit. The pointer is made of a tungsten welding electrode 0.093 in. (2.4 mm) in diam-



The Tangs of the Slotted Cap are bent slightly inward to provide a spring force that holds the cap snugly on the sensor mount.

eter, with its tip sharpened to a point.

Before welding begins, the cap is slipped over the sensor mount, and the mount is adjusted so that the pointer aims at the desired location where the weld puddle will be formed. The alignment tool can be installed and removed without the aid of other tools. The length of the pointer can be adjusted with set-screws. The alignment tool can thus be used with a variety of gas cup and electrode lengths.

This work was done by Jeffrey L. Gilbert and Alfred P. Steffins of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29823

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Robotic Welding of Injector Manifold

The history of a conversion from manual to automated welding is recounted.

A brief report presents a history, up through October 1990, of continuing efforts to convert from manual to robotic gas/tungsten arc welding in the fabrication of the main injector inlet manifold of the main engine of the Space Shuttle. This manifold has many weld joints of complicated shapes that were not amenable to automated welding before 1986, when the manufacturer acquired robotic welding equipment. The decision to convert to robotic welding was motivated by the observation that despite best efforts, manually welded joints were often substandard and had to be reworked.

In the early stage of development of the robotic welding process, there was a concomitant effort to change from typical U-groove weld preparations to machined square-butt joints, with the hope of reducing preparation time, the number of weld passes, and overall shrinkage and distortion. However, postweld inspections revealed that the resulting drop-through of the weld and wider-than-normal cover pass raised new concerns about quality and stress. Consequently, it was decided to revert to U-groove preparation.

The U-groove preparations of the joints of the first production manifold were performed manually. Eight joints with a total length of 56 in. (1.42 m) were welded robotically, using eight of the nine available axes of robotic motion to maneuver the manifold for welding in the downhand position. ("Downhand position" means that the welding torch is oriented vertically above the workpiece, and the workpiece is maneuvered continually to keep the weld joint and surfaces of the workpiece under the tip of the welding torch horizontal during the welding pass along the joint.)

The combination of U-groove preparation and robotic welding resulted in an overall superior final welded manifold, with welds of high quality that satisfied all requirements. The production of subsequent manifolds will take less time because the U-joint preparations will be performed by machine instead of manually and because the time necessary to program the robot was already spent on the first manifold.

The report includes photographs of welding machinery, welds, and weld preparations. Despite its specialized emphasis, it may be of interest to engineers who are considering the establishment of robotic-welding facilities.

This work was done by Jeffrey L. Gilbert and D. Mark Shelley of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Robotic Welding of the Main Injector Inlet Manifold (Hot Dog)," Circle 11 on the TSP Request Card.*
MFS-29822

Planning Assembly of Large Truss Structures in Outer Space

Assembly sequences are planned by use of a graph-search algorithm.

A report discusses a developmental algorithm to be used in the systematic planning of sequences of operations in which large truss structures are to be assembled in outer space. Whether robots or humans are to assemble a given structure, the special requirements of the outer-space operating environment necessitate careful planning to guarantee assembly in a correct and efficient sequence. In particular, even trained humans may fail to detect dead-end parts of a sequence until much work has been done and it is found that the overall assembly task cannot be completed.

It is assumed that the structure will be assembled one strut at a time. The main feasibility condition for a given step in the sequence is the accessibility of the site into which the strut is to be inserted. The assembly-planning algorithm determines accessibility of each site via a relational data structure, in which the truss structure is represented by entities [units (polyhedral partial truss structures), faces (of the units), edges, and vertices], contain/contained relationships, and in-contact relationships.

The assembly sequence is represented by a directed graph called the "assembly graph," in which each arc represents the joining of the two parts or subassemblies. Taking account of the feasibility conditions, the algorithm generates the assembly graph, working backward from the state of complete assembly to the initial state, in which all parts are disassembled. Working backward is more efficient than is working forward because it avoids the intermediate dead ends.

The core of the assembly-planning algorithm is a "best-first" graph-search subalgorithm that includes a cost function. The cost of a given assembly sequence (represented by a path through the assembly graph) increases with the complexity of the task, the distance traveled along the struts by the assembler, and the time required to complete the task. The cost function can also include a reward (in the form of a reduction in cost) for a sequence that results in a more-rigid intermediate structure.

This work was done by Luiz S. Homem de Mello and Rajiv S. Desai of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Assembly Planning for Large Truss Structures in Space," Circle 98 on the TSP Request Card.*

NPO-18257

Mathematics and Information Sciences

Transverse Mercator Projection Via Elliptic Integrals

An entire hemisphere can be mapped to within 1 mm.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of construction of the U. S. Army's universal transverse Mercator grid system is based on the Gauss–Kruger (constant-meridional-scale) transverse Mercator projection and on the use of elliptic integrals of the second kind. The method can be used to map the entire northern or southern hemisphere with respect to a single principal meridian.

The mapping process begins with the conventional polar stereographic projection, in which each point of interest on the hemisphere of interest is mapped to a point inside the unit circle on a plane. The mapping of each point is accomplished by a use of a closed-form function of its conventional geodetic coordinates, which are its colatitude and the departure of its longitude from the principal meridian. Another closed-form function gives the parametric colatitude — i.e., the complement of what is called the "reduced latitude" — as a function of the geodetic colatitude.

A closed-form composite of these two closed-form functions is constructed. The composite function is analytic, and its derivative also has closed form. The composite function can, therefore, be inverted by Newton–Raphson iteration. Such an iteration is performed to solve for that value of the tangent of half the parametric colatitude that makes the value of the composite function equal the complex value of the polar stereographic projection of the geographic point in question. This determines the complex-valued tangent of half the amplitude of an incomplete elliptic integral of the second kind. The integral is then computed, and the result is the Gauss–Kruger transverse Mercator projection.

Unlike some other methods, this one involves no mathematical sensitivity (e.g., singularities) to (1) proximity to the pole or equator or (2) longitudinal departure from the principal meridian. The availability of the amplitude makes it possible to use exact transformations of the elliptic integral to smaller moduli and amplitudes to obtain a rapidly convergent approximation (two steps of transformation are enough).

Other than the elliptic integrals, the only transcendental functions needed in this method are the elementary ones (e.g., arctangent, etc.). The accuracy of the resulting map grid — 1 mm at present — is limited only by the number of decimal places to which the computations can be carried with the available computing hardware and software.

This work was done by David E. Wallis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 19 on the TSP Request Card.*
NPO-17996

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Numbers of Degrees of Freedom of Allan-Variance Estimators

Algorithms for closed-form approximations of numbers of degrees of freedom are presented.

A report discusses formulas for the estimation of Allan variances ("Allan-variance estimators" for short). It presents algorithms for closed-form approximations of the numbers of degrees of freedom that characterize the results that are obtained when the various estimators are applied to the five power-law components of the classical mathematical model of clock noise.

To explain both the foregoing summary and some of the details of the report, it is necessary to devote several paragraphs to the definition of terms. Consider two clocks that are governed by oscillators of nominally the same frequency. Let $X(t)$ be the difference between the times indicated by the two clocks at exact time t. If both clocks are observed at increments τ of exact time, then the second increment of the difference is defined by $Z(t,\tau) = X(t+2\tau) - 2X(t+\tau) + X(t)$. The Allan variance, $\sigma_y^2(\tau)$, is defined by

$$\sigma_y^2(\tau) = \frac{1}{2\tau^2} E[Z(t,\tau)]^2$$

where E denotes the expectation operator. The Allan variance is the standard measure of mean-square fractional deviation of the frequency of one clock with respect to the other.

Suppose that N samples $X_i = X(i\tau_o)$ (where $i = 1$ to N) have been taken at equal intervals τ_o. Let $\tau = n\tau_o$ where n is an integer less than $N/2$. Then one can form $M = N - 2n$ samples of $Z(t,\tau)$; namely, $Z_i = X_i - 2X_{i+n} + X_{i+2n}$ (where $i = 1$ to M). The maximal-overlap estimate of $2\tau^2\sigma_y^2(\tau)$ is defined as the average of the squares of the Z_i and is given by

$$V(M,n,\tau_o) = \frac{1}{M}\sum_{i=1}^{M} Z_i^2$$

The τ-overlap estimate of $2\tau^2\sigma_y^2(\tau)$ is obtained by using only every nth Z_i and is given by

$$V(m,1,\tau) = \frac{1}{m}\sum_{j=1}^{m} Z_{1+n(j-1)}^2$$

where $m = \mathrm{Int}[(N-1)/n)] - 1$, the number of τ-interval samples of $Z(t,\tau)$, and $\mathrm{Int}(x)$ is the greatest integer contained in x.

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Both the maximum-overlap and the τ-overlap estimators are positive and unbiased. A measure of quality that can be applied to a positive unbiased estimator V, that exhibits a finite variance is its number of degrees of freedom, ν, defined by

$$\nu = 2[E(V)]^2/(\text{Variance of } V)$$

If the distribution of V is that of a constant times a χ^2 random variable, then ν equals the number of degrees of freedom of the χ^2 distribution, and the probability levels of the χ^2 can be used to derive confidence intervals for the unknown value $E(V)$. This completes the lengthy but necessary definition of terms.

The purpose of the report is to present a set of algorithms for computation of the numbers of degrees of freedom of maximum-overlap and τ-overlap estimators. Although exact closed-form equations for all the components of the standard mathematical model of clock noise cannot be found, one can obtain approximate equations, the maximal errors of which are about 1 percent for all $M \geq 1$ and $n \geq 1$. These approximate equations are incorporated into the algorithms, which are presented in an informal pseudo-computer language that resembles BASIC and FORTRAN and can be formalized in about three pages of BASIC or FORTRAN code. The report concludes with a discussion of the uses and limitations of the Allan variance and with suggestions for further research.

This work was done by Charles A. Greenhall of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Recipes for Degrees of Freedom of Frequency Stability Estimators," Circle 7 on the TSP Request Card.*
NPO-18383

Recursive Inversion of Externally Defined Linear Systems

The recursive approximation by a finite-impulse-response technique is revisited.

A technical memorandum discusses the mathematical technique that was described previously in "Recursive Inversion by Finite-Impulse-Response Filters" (ARC-12247), *NASA Tech Briefs* Vol. 15, No. 1 (1991), page 51. The technique is a recursive algorithm that yields a finite-impulse-response approximation of an unknown single-input/single-output, causal, time-invariant, linear, real system, the response of which is a sequence of impulses. The technique could be useful in such diverse applications as medical diagnoses, identification of military targets, geophysical exploration, and nondestructive testing.

As in the study described in the noted previous article, the problem is to use the response of the system to a known input to deduce an approximate mathematical model of the system, which is regarded as a "black box." The finite-impulse-response approximation satisfies a least-squares best-fit criterion, and the recursion has an exact initialization, which is based on the lower triangular Toeplitz structure of one of the impulse-response matrices. The recursive least-squares inversion is shown to converge to an approximation of the system, provided that the system is externally stable. Furthermore, as one would expect intuitively, the error of the inversion diminishes toward zero as the length of the inverse filter (the number of impulses considered) increases toward infinity.

This work was done by Ralph E. Bach, Jr., and Yoram Baram of **Ames Research Center**. *Further information may be found in NASA TM-100070 [N88-19215], "Recursive Inversion of Externally Defined Linear Systems."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12353

Human Factors of Flight-Deck Checklists

Such checklists should be designed to accommodate human strengths and limitations.

A report analyzes the functions, formats, designs, lengths, and usage of normal cockpit checklists, as well as the limitations of the aircraft personnel who must interact with them. The checklist problems discussed in this report can also be found in other high-risk industries — for example, the marine, nuclear, and chemical-process industries — as well as civilian and military air transportation.

The sources of information for the analysis included field studies in airline aircraft; interviews with "line" pilots from seven major U.S. airlines; incident and accident reports from NASA's Aviation Safety Reporting System, the National Transportation Safety Board, and the International Civil Aviation Organization; interviews with officials from the Federal Aviation Administration and from the National Transportation Safety Board; aircraft and avionics manufacturing companies; and general literature in the fields of aviation, psychology, typography, and human performance. The objectives of this study were the following:

- To understand the role of the checklist in the operation of a modern transport aircraft;
- To identify the factors that contribute to the misuse or nonuse of checklists; and
- To present guidelines for the design of checklists.

The major function of the checklist is to ensure that the crew will properly configure the plane for flight and maintain this level of quality throughout the flight. The process of conducting a checklist occurs during all segments of a flight and, in particular, prior to the critical segments (takeoff, approach, and landing). Although the combined durations of these segments amount to only 27 percent of the duration of an average flight, these segments account for 76.3 percent of hull-loss accidents. To promote a positive attitude toward the use of the checklist procedure, the checklist must be well grounded within the current operational environment, and the operator must have a sound realization of its importance, instead of regarding it as a nuisance task.

Among the proposed guidelines for the design and use of flight-deck checklists are the following:

- Every effort should be made to avoid using the checklist as a "dumping site" for the resolution of discipline problems.
- Standardization of checklists among different types of aircraft should be done carefully to prevent the inappropriate imposition of the checklist sequence and concept of one type of aircraft upon another.
- Airlines should attempt to standardize the names assigned to controls and displays in different types of aircraft.
- The most critical items on the portion of a checklist applicable to a specific task ("task checklist" for short) should be listed as close as possible to the beginning of the task checklist, to increase the likelihood of completing the task before interruptions may occur.
- Critical checklist items such as flaps/slats, trim setting, etc., that might need to be reset due to new information (arriving after their initial positioning), should be duplicated prior to takeoff.
- Checklists should be designed in such a way that the execution of them will not be tightly coupled with other tasks. Every effort should be made to provide buffers for recovery from failure and to provide a way to "take up the slack" if the completion of a checklist does not keep pace with the external operation.
- Flight crews should be made aware that the checklist procedure is highly susceptible to production pressures. These pressures set the stage for errors by encouraging substandard performance and later may lead some to relegate checklist procedures to second level of importance, or not use them at all, to save time.
- FAA officials, particularly Principal Operations Inspectors, should be sensitive to cultural, traditional, and philosophical factors in airline companies and the effects of these factors on checklists submitted for their approval.
- When a merger occurs, checklists of the acquired airline should be carefully examined for their differences from those of the acquiring airline. Knowledge gained by the acquired airline in operating a specific model should not be ignored. Differences in concepts and operating procedures should be resolved in a manner that enhances safe checklist behavior of all crewmembers.

This work was done by Asaf Degani of San Jose State University and Earl L. Wiener of the University of Miami for **Ames Research Center**. *Further information may be found in NASA CR-177549 [N91-27144], "Human Factors of Flight-Deck Checklists: The Normal Checklist."*

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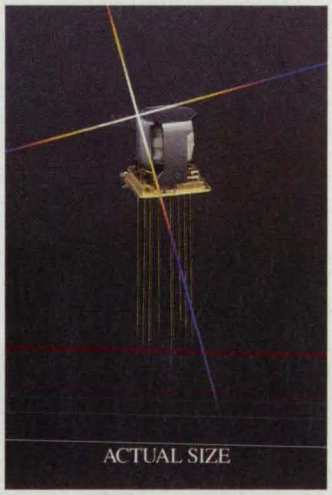

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Liquid-Spray Formulation of Scopolamine

Drops can be administered intranasally to obtain fast relief from motion sickness.

Lyndon B. Johnson Space Center, Houston, Texas

Scopolamine, a fast-acting anticholinergic drug, has been formulated into drops that can be administered intranasally. This formulation should be very useful for people who need immediate relief from motion sickness, and they can administer it to themselves. This formulation could also be used in other clinical situations in which a fast-acting anticholinergic medication is required: for example, preoperative medication, dilation of pupils in ophthalmology, and adjunct anticholinergic therapies. It could be modified into such other forms as a gel preparation, an aqueous-base ointment, or an aerosol spray or mist; it could also be dispensed in a metered-dose delivery system.

Previously, scopolamine has been administered intravenously or orally. However, intravenous administration is invasive and requires special technical expertise and equipment, and oral administration is unreliable and often ineffective.

The recipe for the intranasally administrable formulation is as follows:

1. Prepare a methylcellulose vehicle solution by putting 20 mg of methylcellulose in 800 mL of a sterile 0.9-percent sodium chloride solution and stirring until the methylcellulose is dissolved.
2. Add 75 mL of a 1:750 aqueous solution of benzalkonium chloride.
3. Add 4,000 mg of scopolamine hydrobromide, and stir until dissolved.
4. Adjust the pH to 4 ± 0.2 by use of 1:100 phosphoric acid buffer.
5. Make the final volume 1,000 mL by adding a 0.9-percent sodium chloride solution.
6. Label with lot number and date of manufacture.
7. Analyze the preparation for scopolamine content by use of an established high-performance liquid-chromatographic method.

The formulation is a nonirritant solution that can be easily instilled in the nasal cavity. Because of its aqueous nature, the solution can be prepared very easily, without need for any special equipment. This is the first noninvasive, fast-acting, reliable, and inexpensive-dosage formulation of scopolamine.

This work was done by Lakshmi Putcha and Nitza M. Cintrón of **Johnson Space Center**. *For further information, Circle 100 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21858.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Cells in Space

Aspects of the study of cells in microgravity are discussed.

The report of the "Cells in Space —II" conference held from 31 October through 4 November 1988 in San Juan Bautista, CA, contains abstracts of 32 oral presentations discussing 3 aspects of cell research in space: (i) the suitability of the cell as a subject in microgravity experiments, (ii) the requirements for generic flight equipment to support microgravity cell research, and (iii) the potential for collaboration between academia, industry, and government to develop these studies in space. In addition, the report contains 19 of the conference papers and presentation viewgraphs for 4 papers, gives synopses of the presentations and of follow-on discussions at the conference, and provides an executive summary outlining the recommendations and conclusions generated at the conference.

The presentations were apportioned among seven sessions denoted by the following titles:

Session I	Does Microgravity Affect Cell Structure and/or Cell Function?
Session II	Biophysical Phenomena and the Gravity Response
Session III	Gravity Unloading — Understanding the Input and Output Mechanisms of the Organism Responsible for the Transformation of Inertial Acceleration into a Response
Session IV	Hardware Design Concepts and Other Factors Which Can Influence Cell Biology in Space
Session V	Investigator Sensitization to Mission Requirements and Constraints
Session VI	Experimental and Commercial Applications in Microgravity
Session VII	Facilitator Summaries and Attendee Input for Future Experiments in Space

The following conclusions and recommendations emerged from the conference:

- Gravity does affect metabolism at the cellular level.
- Clinostat experiments are essential adjuncts to flight experiments.
- Terms used in gravitational biology should be clearly defined.
- The effects of gravity must be understood at the cellular, and even at the molecular, level.
- The responses, to gravity, of cells in suspension may differ from those of cells grown in a monolayer attached to a substrate or of cells fixed in solid tissue.
- The development of bioreactors for studies in outer space should continue.
- The development of generic equipment should be considered as a means to reduce the costs of missions and to facilitate experimentation.
- The potential for commercial applications in outer space exists, as evidenced by work in pharmaceuticals and the growth of protein crystals.

This report was edited by P. X. Callahan and C. M. Winget of **Ames Research Center**, *J. D. Sibonga and R. C. Mains of Mains Associates, and T. N. Fast of the University of Santa Clara. Further information may be found in NASA CP-10034 [N90-13937], "Cells in Space."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12803

Antigravity Suits for Studies of Weightlessness

Positive pressure in the lower body produces physiological effects similar to those of weightlessness.

A report presents the results of research on the use of an "antigravity" suit — one that applies positive pressure to the lower body to simulate some of the effects of microgravity. The research suggests that lower-body positive pressure (LBPP) is an alternative to bed rest or immersion in water in terrestrial studies of cardioregulatory, renal, electrolyte, and hormonal changes induced in humans by microgravity.

The report discusses cardiovascular adjustments to gravity, cardiovascular deconditioning and adaptation, terrestrial methods of simulating weightlessness, and applications of antigravity suits (which include clinical as well as research uses). It also includes reprints of several papers that describe research based on antigravity suits and related topics. An antigravity suit is essentially a pair of trousers that encloses the legs and abdomen with inflatable bladders. The bladders are pressurized with air or, less frequently, water. Such suits have been used since the early years of World War II to reduce the effects of high acceleration on pilots.

The research showed that subjects who wore antigravity suits in upright postures experienced migration of body fluids toward their heads — one of the most noticeable effects of weightlessness. Some of the changes in body fluids were similar to those observed during immersion in water.

The antigravity suit offers major advantages over bed-rest and immersion-in-water studies of the effects of weightlessness. It does not restrict postures for example; subjects can sit, lie, stand, and even walk. The suit can be donned and doffed quickly and easily, without the help of highly trained personnel. Pressures within the suit can be adjusted quickly to provide a wide range of experimental conditions. It eliminates the need for the cumbersome water tank and accompanying temperature-control apparatus of immersion experiments and for the many days of inactivity and supine posture of bed rest.

This work was done by Stein E. Kravik, and John Greenleaf of **Ames Research Center**. *Further information may be found in NASA TM-102232 [N90-13013], "Cardiovascular, Renal, Electrolyte, and Hormonal Changes in Man during Gravitational Stress, Weightlessness, and Simulated Weightlessness: Lower Body Positive Pressure Applied by the Antigravity Suit."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-12804

Effect of Contrast on Perceived Motion of a Plaid

The perceived motion is biased toward that of the component of higher contrast.

A report describes a series of experiments examining the effect of contrast on the perception of moving plaids. Each plaid pattern used in the experiments was the sum of two drifting sinusoidal gratings of different orientations. This is one of many studies that are helping to show how the brain processes visual information on moving patterns. When the gratings forming the plaid differ in contrast, the apparent direction of motion of the plaid is biased up to 20° toward the direction of the grating of higher contrast.

The report reviews prior observations and models of how the brain detects motions of gratings. According to one prior model for moving plaids, the perceived motion is independent of contrast. The model involves a two-stage process in

which the visual system in the brain analyzes the motion of a plaid by first decomposing it into the motions of the two component gratings, then determining the velocity of the plaid to lie at the intersection of two constraint lines perpendicular to the component velocity vectors at their heads. However, it was shown in a previous study that the perceived speed of a single grating is a function of contrast. This fact leads to the hypothesis that this dependence on contrast is passed on to the second stage of processing, leading to a significant contrast-dependent distortion of the perceived motion of the plaid. The experiments were intended to test this hypothesis.

In the experiments, a computer-driven video terminal was used to generate the moving plaid stimulus and display it to four observers. The spatial period of the two gratings was 1.5 cycles per degree. Both gratings were oriented 60° from vertical. To avoid clues from edges, the plaid was displayed through a circular hazy and fuzzy-edged window defined by contrast proportional to a Gaussian function of radius from the center. Prior to the main experiment of the study, the contrast-threshold sensitivity of each subject for the detection of the component gratings was measured. In the main experiment, runs were taken with total grating contrasts of 5, 10, 20, and 40 percent.

After discussing the quantitative characteristics of the results and reviewing other contrast-response phenomena reported in the literature, the report notes that an interesting finding of this and other studies is not that there are contrast-dependent misperceptions of motion but that most of these misperceptions occur only at the extreme low end of the contrast scale.

The results show that, among other things, the apparent direction of motion of the plaid is biased as much as 20° toward the component grating of higher contrast. In most cases, the new observations are shown to be consistent with a modified version of the two-stage model, in which contrast-distorted estimates of the speeds of the two grating components constitute the velocity inputs to the second stage of processing.

This work was done by L. S. Stone, A. B. Watson, and J. B. Mulligan of **Ames Research Center**. *Further information may be found in NASA TM-102234 [N90-15577], "Effect of Contrast on the Perception of Direction of a Moving Pattern."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12802

Safer Weightlessness Simulator

A water-immersion system maintains atmospheric pressure to prevent the bends.

A system described in a report simulates the weightlessness of space for the training of astronauts, without the adverse effects of rapid decompression. As in previous simulators, a trainee wearing a space-suit performs training exercises while immersed in water; the buoyancy of the water negates much of the effect of gravity. In the new system, however, the space-suit interior is not above atmospheric pressure. There is therefore no need for the trainee to undergo gradual decompression to prevent the bends (caisson disease) after a lengthy exercise; nor is there any need for a medical team to be present.

In a conventional immersion system, the water pool is open to the atmosphere. The difference in pressure between the inside and the outside of the space suit must be the same as in space for the suit to have the same flexibility and feel. This means that the internal pressure must be substantially above atmospheric in the pool; for the space-station suits, for example, the dif-

ferential is 8.3 lb/in.^{2} (57 kPa). Under such conditions, the wearer absorbs excess nitrogen in the bloodstream and could develop the bends unless the exposure time is limited or the wearer is slowly depressurized after leaving the pool.

In the new system, the pool is in a sealed chamber maintained at a low pressure by a vacuum pump. The trainee enters the chamber — and, simultaneously, the space suit — through a port. An opening in the upper back of the suit is sealed to the periphery of the port and is open to the atmosphere. The trainee stands on a platform inside the chamber and performs the assigned tasks. The port is always open to the atmosphere, and the trainee can leave through the port at any time.

In an alternative version of the system, the suit would not be fixed to the chamber. Instead, the trainee would enter through the port, don the suit — which would be supplied with outside air through hoses— and wait while the tank is filled with water and depressurized by the vacuum pump. The trainee would then be able to move about in simulated weightlessness in the chamber.

This work was done by Hubert C. Vykukal of **Ames Research Center**. *To obtain a copy of the report, "Weightlessness Simulation System and Process," Circle 9 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,678,438). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 20]. Refer to ARC-11646.

Controlled Ecological Life-Support Systems

Papers from a meeting on production of edible biomass in space are compiled.

A document contains the proceedings of the February, 1989 meeting of Scientists of NASA's Controlled Ecological Life Support Systems (CELSS) program. The document includes 25 scientific papers and a bibliography of CELSS documents published as NASA reports.

The program assembled a diverse group of investigators to discuss topics relevant to bioregenerative systems for piloted space missions early in the next century. Attendees were drawn from NASA centers and from universities and industry in the United States.

Subjects range from studies of the efficiency of the growth of plants to conversion of inedible plant material into edible food. Models of the growth of plants and of whole CELSS systems are included. The use of algae to supplement and improve diets is addressed.

Several papers discuss the development of CELSS technology, both based on the ground and qualified for flight. Work at the Breadboard Facility of Kennedy Space Center and the Ames Crop Growth Research Chamber at Ames Research Center is described. Experimentation in flight is discussed from the perspectives of topics that range from a salad machine for Space Station Freedom to conceptual designs for a CELSS to be used at a station on the Moon.

Issues that relate to control subsystems are reviewed, and recommendations are made for the development of a robust control system. The processing of waste materials is discussed, with attention to the analysis of physicochemical, biological, and hybrid systems and to the effects of characterization of sources of waste on the criteria for the design of such systems.

This document was edited by Robert D. MacElroy of **Ames Research Center**. *Further information may be found in NASA TM-102277 [N91-31775], "Controlled Ecological Life Support Systems: CELSS '89 Workshop."*

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For More Information Circle No. 560

Effects of Stress on Bone-Formation Markers in Rats

There was dissociation between two markers in rats that endured space flight followed by stress.

A report describes experiments that involved simultaneous measurement of the concentrations, in blood, of two substances indicative of the formation of bone in rats. The measurements were performed after flight in outer space plus 48 h of post-flight environmental stress. The results emphasize the critical influences of the adrenal status and diet on the functions of osteoblasts.

The substances in question are osteocalcin (OC) and heat-sensitive alkaline phosphatase (ALP). Two main groups of rats were used: 20 in the flight experiment and 30 in a pilot (control) experiment on the ground. Both experiments were scheduled for two weeks.

The flight rats were housed in subgroups of 10 in group cages in the Cosmos 1887 biosatellite for 12.5 days. During that time, the rats consumed a paste diet (diet R), about 55 g/day in four portions. Because the satellite landed off course, the animals were on the ground for 2 days in the biosatellite, which lost some temperature control. During this time, the rats had drinking water but were fed only one meal. In comparison with the control rats, the flight rats had reduced levels of serum OC, but unchanged levels of ALP.

In the flight rats, the decrease in the serum OC level was correlated with a decrease in overall body weights and with an increase in the relative weights of the adrenal glands. According to the authors, these observations, plus the awareness of the capacity of the adrenal gland to gain weight during short periods of environmental stress, support the opinion that the acute increase in the production of steroids associated with the stress caused by the landing (instead of by the space flight) was a major factor in the reduction of the OC serum levels superimposed on a reduced osteoblast cell population from space flight.

Rats in the pilot group were divided into four subgroups according to housing and diet. The rats in subgroups 1 and 2 were housed 10 per cage in group cages identical to those of the flight rats. The rats in subgroups 3 and 4 were housed singly. The same paste diet (diet R) consumed by the flight rats was given to subgroups 1 and 3, and Teklad diets were given to subgroups 2 and 4. (Diet R differed from the Teklad diet in that it contained no flour and had a higher percentage of fat.)

In the pilot study, the OC levels were influenced primarily by the nutritional status of vitamin D, which was normal in the flight animals but was reduced by single caging in the pilot study. ALP varied with the quantity of food or with unidentified elements in the diet. Rats that gained weight more rapidly with Teklad diets had higher levels of ALP and serum calcium than did rats fed the flight diet (diet R). OC levels were similar in the two dietary groups but were lower in single-caged rats than in group-caged rats; the single-caged rats had higher adrenal weights and lower levels of 25-hydroxylated vitamin D than did group-caged rats. The decrease in the levels of OC in singly caged rats, which are presumed to have been under more stress than were group-caged rats, is consistent with a role of post-flight stress in the reduced levels of OC in flight rats..

This work was done by Sara B. Arnaud, Paul Fung, Marilyn Vasques, and Richard E. Grindeland of **Ames Research Center**, *Patricia Patterson-Buckendahl of the University of California at Santa Cruz, and Galina Durnova of the Institute for Biomedical Problems, USSR Ministry of Health. To obtain a copy of the report, "Dissociation of Bone Formation Markers in Rat Serum After Spaceflight," Circle 27 on the TSP Request Card.*
ARC-12799

New on the Market

Evans & Sutherland Computer Corp., Salt Lake City, UT, and Sun Microsystems Computer Corp., San Francisco, CA, have unveiled the Freedom™ **graphics accelerator** family for the SPARC®/Solaris™ platform. Offering twice the 3D graphics speed of available workstations, the accelerators use Sun's standard open graphics hardware and software interfaces, and are customer-installable to SPARCstations 2 and 10 via a single SBus card.
For More Information Circle No. 800

The industry's first fully-digital, **on-line battery backup unit** is available from DSK Inc., Orem, UT. The Perfector Series™ UPS employs high-speed digital technology to ensure a perfect sinewave. All incoming power is converted to a simple energy level and then processed into perfect AC power. High-speed wave generators provide minimal battery drain, permitting 92-98% efficiency.
For More Information Circle No. 798

The Capattery™, a high-reliability, double-layer **capacitor**, has been announced by Evans, East Providence, RI. It features 20 times the capacitance density of conventional capacitors (in excess of 30 farads per gram of activated carbon), essentially unlimited cycle life, and stable operating performance from -55 to +85° C. It can serve as a standby power source in memory back-up and bridge-power applications.
For More Information Circle No. 792

The XC-999 **miniature CCD color camera/controller** from Sony Corp. of America, Cypress, CA, is smaller and lighter than current models. Measuring less the five inches long, the XC-999 incorporates a high-resolution Hyper HAD™ CCD sensor for light sensitivity down to 4.5 lux and features a signal-to-noise ratio of more than 48 dB.
For More Information Circle No. 794

A line of self-powered **data loggers** called JETS has been developed by IOPOD Robotics Corp., Surrey, BC. Just two inches long, they feature fast optical data transfer, waterproof operation, and a ten-year lithium battery. The JETS record and measure temperature, humidity, switch status, resistance, machine runtime, voltage, current, process signals, pulses, and other variables.
For More Information Circle No. 788

Data I/O Corp., Redmond, WA, is offering a **device programming base** that allows engineers to utilize the new high-density programmable integrated circuits such as FPGAs and Complex PLDs. Dubbed the Package-Pinout Interface System, it supports the various surface-mount package styles that house these devices and improves both programming reliability and yield. It eliminates the need for add-on adaptors and will accommodate a wide range of packages, pinouts, and high pin-count devices.
For More Information Circle No. 796

BitWise Designs Inc., Schenectady, NY, has introduced ScreenStar™, a **mobil 486 workstation** constructed within a composite suitcase shell. Measuring 22" x 19", it provides a 21.3" glass plasma display screen with 1280 x 1024 pixel resolution that displays two 8½" x 11" documents. ScreenStar is driven by a 50 MHz 80486DX CPU with 8 MB of 60 ns RAM, 256 KB of cache RAM, and 200 MB of disk storage.
For More Information Circle No. 790

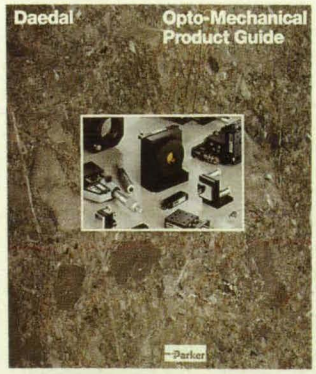
New Literature

A new catalog from the Motion & Control Division of Pacific Scientific Co., Rockford, IL, describes the company's **brushless servosystems, stepper systems, and hybrid step motors**. Products range from economical OEM motors and drives to intelligent plug-and-play position control systems for multi-axis use. The publication includes a technology overview that weighs the merits of brushless servo and stepper systems in specific applications.

For More Information Circle No. 706

A brochure released by General Magnaplate Corp., Linden, NJ, highlights "synergistic" **coatings** that put a harder-than-steel, dry-lubricated, nonstick surface on ferrous and nonferrous metals in extremely high and low temperatures. The coatings—including TUFRAM®, NEDOX®, and PLASMADIZE®—become an integral part of the metal surface. They resist corrosion, chemical attack, and abrasion while improving mold release, material flow, and sanitation.

For More Information Circle No. 714



Daedal, a division of Parker Hannifin Corp., Harrison City, PA, has introduced the *Opto-Mechanical Source Book*, a catalog of **scientific laser and optical products**. It features high-precision ball bearing, cross roller, and sub-miniature stages, digital micrometers, coated mirrors, mirror mounts, and steering devices.

For More Information Circle No. 712

Spyglass Inc., Champaign, IL, has published *The Data Handbook: A Guide to Understanding the Organization and Visualization of Technical Data.* This desk reference reviews how data is stored on a computer; how it is organized as a column of numbers, 2D matrix, 3D matrix, or list of polygons; and how to effectively store and visualize it.

For More Information Circle No. 704

A 288-page catalog from Data Translation, Marlboro, MA, details **test and measurement, data acquisition, image analysis, chromatography, and line scan products** for the IBM PC/XT/AT and compatibles, IBM PS/2, Macintosh II, VMEbus, MicroVAX, and iSBX Bus. The handbook features new products for PC AT-based hardware and DT-Open Layers™-compliant software including the DT3801 series single-board test and measurement system.

For More Information Circle No. 708

A 1500-page **instruments** catalog from Cole-Parmer Instrument Co., Niles, IL, describes more than 35,000 products. New items include process indicators and controllers, Gilmont Accural flowmeters, pH/ORP indicators, chart recorders, and improved Masterflex® pumps and controllers. The catalog features technical data and conversion factors, a chemical resistance chart, and a fittings section.

For More Information Circle No. 702

High-performance **engineering polymers and acrylic monomers** are showcased in a brochure from Elf Atochem North America Inc., Philadelphia, PA. Featured products include Rilsan® polyamides, offering lower moisture absorption than other nylons; Pebax® thermoplastic elastomer resins, with performance characteristics to bridge the gap between plastics and rubber; and Platamid® and Platherm® hot melt adhesives, high molecular weight polyamide and polyester copolymers that are 100% solids and solvent-free.

For More Information Circle No. 710

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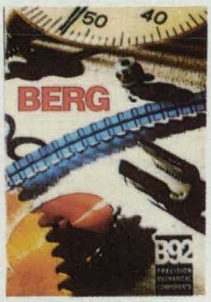

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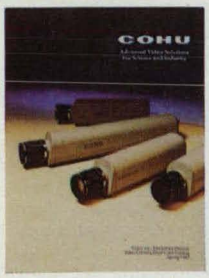

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Security/surveillance applications: Circle No. 305

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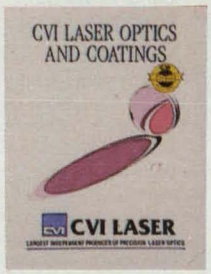
For More Information Circle Action No. 307



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For More Information Circle Action No. 308

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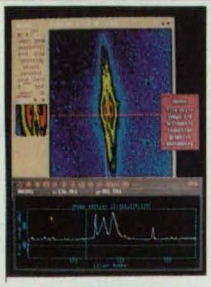

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Saguaro Scientific Corporation

For More Information Circle Action No. 313

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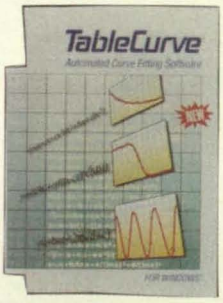
Alpha Omega Instruments Corp.

For More Information Circle Action No. 316



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For More Information Circle Action No. 317

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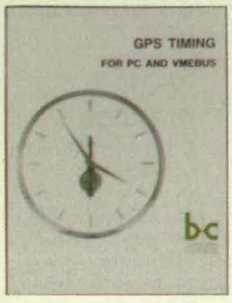
Brochure includes free wall chart that lists 500 ways to use K-Flow® Coriolis mass flow meters for hundreds of fluids—for acids, oils, resins, water, emulsions, and more! Measure mass flow, density, temperature, net flow, concentration, %'s solids/liquids, and specific gravity; and with accuracies to better than 0.25% for flows from a few cc's to 2,000 lbs/min. K-Flow®'s software rich flow computer even runs many control devices by itself, saving time and money. Call today for complete info! 800-82K-FLOW.

For More Information Circle Action No. 318

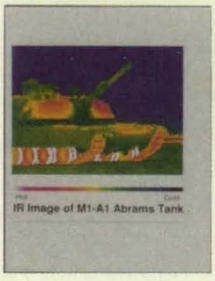


GPS TIMING FOR PC AND VMEBUS

This information folder from Bancomm describes new PCbus and VMEbus board-level Global Positioning System (GPS) Satellite Receivers. These products provide world-wide precision time (100 nanosecond) and frequency (1 part in 10E7) references inside the host computer.

Bancomm

For More Information Circle Action No. 319

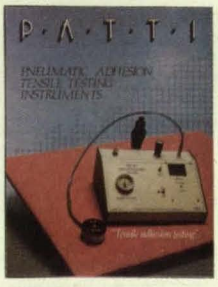


SEE THE HOT SPOTS?

An M1-A1 tank may not be attacking you now, but a hot spot probably is. Industrial and research infrared cameras are available to get or keep you out of the hot seat. For more information call 513-573-6275, or Fax 513-573-6290. Address is 7500 Innovation Way, Mason, OH 45040.

Cincinnati Electronics, Detector Labs.

For More Information Circle Action No. 320

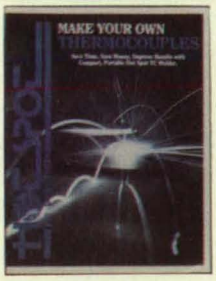


COATING ADHESION TESTERS

Measures the strength of paints, coatings, and adhesives. Surface can be smooth, rough, or porous. True tensile strength is measured with a pneumatic piston, up to 10,000 psi. Analog and digital models meet ASTM D4541.

SEMicro Corp.

For More Information Circle Action No. 321



THERMOCOUPLES, MAKE YOUR OWN

The HOTSPOT allows thermocouple wire to be formed into freestanding junctions, or welded to metal surfaces. It provides a simple means of fabricating thermocouples "when needed and where needed". Brochure and specification sheet available.

DCC Corp.

For More Information Circle Action No. 323

POLYMERS & ACRYLIC MONOMERS

A new, 12-page four-color brochure titled "Engineering Polymers and Acrylic Monomers." Included are polymers and monomers family of products, including Rilsan® 11 and 12 polyamides; Rilsan® powder coatings; Pebax® thermoplastic elastomer resins; Platamid® and Platherm® hot melt adhesives; Platilon® hot melt film; and acrylic monomers. Product description, background, and a sampling of applications are also provided.

Elf Atochem North America, Inc.

For More Information Circle Action No. 324

MAINTAIN YOUR COOL

Barnstead offers a wide variety of cartridges and holders designed to provide deionized water for cooling systems. The presence of ions and oxygen can severely hamper the ability of your cooling system to work properly. We offer standard and customized deionization systems to meet your cooling needs. Call now for more information, 800-446-6060, ext. 414.

Barnstead/Thermolyne Corp.

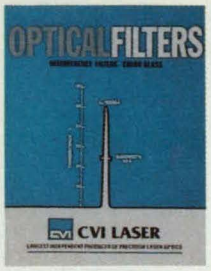
For More Information Circle Action No. 325

NEW! HEAVY-DUTY LOCKING ASSEMBLIES

For zero-backlash connections on shafts from 1 to 8 in. or 30 to 600 mm. Transmit high torques and bending moments. Ideal for reversing and shock loads or timing. Fit through-bored components and provide perfect concentricity. Located in Monroe, NY. Phone: 914-782-5650; Fax 914-783-0271.

Bikon Corporation

For More Information Circle Action No. 326



OPTICAL FILTER CATALOG

CVI's new, 32-page Optical Filters catalog lists an expanded stock of high quality coated neutral density and coated interference bandpass filters, and such color glass filters as bandpass, longwave pass sharp cut, infrared blocking, and absorptive neutral density. The firm's address is 200 Dorado Place SE, Albuquerque, NM 87192. Phone: 505-296-9541; Fax 505-298-9908.

CVI Laser

For More Information Circle Action No. 327

WORKMANSHIP STANDARDS MANUALS

Workmanship Standards were developed by Martin Marietta to use as guidelines in manufacturing electromechanical and electronic systems that perform to exacting government/defense requirements. Photographs and clear instructions provide the individual with a clear definition of what is required on the production line and in training programs.

Martin Marietta Information Systems

For More Information Circle Action No. 328

OVENS & FURNACES CATALOG

Expanded, 4-color capabilities section, illustrated, plus specifications and prices for over 250 ovens and furnaces to 2700 °F and custom designed and field assembled heat processing systems. Includes: laboratory, bench, cabinet, truck, walk-in and conveyor ovens; laboratory and industrial furnaces and environmental test chambers. For baking, drying, pre-heating, annealing, stress relieving, curing, sterilizing and heat treating. Phone: 708-546-8225; Telex: 72-2436; Fax: 708-546-9210.

The Grieve Corp.

For More Information Circle Action No. 329

EMC ACCESSORY/ PRODUCT CATALOG

Comprehensive catalog of EMC accessories and products from CHASE Electronics: Antennas, Tripods, Masts, Probe Sets, LISNs, Pre-selectors, Analyzers and Software. Contact IBEX Group Inc., Phone: 908-722-8085 for all your EMC needs.

IBEX Group, Inc.

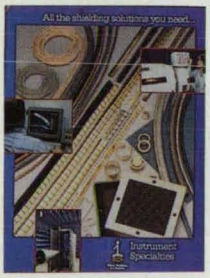
For More Information Circle Action No. 330

INDUCTION HEATING SYSTEM

Unipower brochure describes a line of solid-state replacements for tube oscillators. Features include broad power matching with built-in output transformer, high operating efficiency, ease of use, digital heat timer, and compact benchtop unit for stand-alone operation. Phone: (800) 486-5577 in Fort Worth, TX.

IHS Inductoheat

For More Information Circle Action No. 331



CAPABILITIES BROCHURE

Instrument Specialties has issued a new brochure that covers its design, manufacturing, total quality management and EMC testing capabilities. Titled "All the shielding solutions you need, "the piece also provides detailed information, including shielding effectiveness, key features and available options, for selected products. Phone: (717) 424-8510; Fax: (717) 424-6213.

Instrument Specialties Co., Inc.

For More Information Circle Action No. 332

PXS™ SERIES PORTABLE X-RAY SOURCES

Kevex X-Ray's PXS™ line of portable x-ray sources feature the x-ray tube, high voltage power supply, control electronics and heat exchanger in a single compact package. Each PXS unit is operable from a low level DC source, either 12 VDC or 28 VDC, and an optional controller is available to control and monitor target voltage and electron beam current.

Kevex X-Ray

For More Information Circle Action No. 333

MECHANICAL TESTING LABORATORY

Exclusively devoted to mechanical testing, Mar-Test has provided testing services for a variety of industries including aerospace, transportation and medical for over 20 years. Extensive facilities and experienced personnel ensure quick turnarounds and accurate, reproducible results. Phone: 513-771-2536; Fax: 513-771-2564.

Mar Test, Inc

For More Information Circle Action No. 334

3D MOTION MEASUREMENT

The OPTOTRAK system tracks infrared LED targets in 3D with accuracy of 0.1mm, at rates to 3500 Hz. Position and orientation data calculated in real time. Used for robot metrology, wind tunnel model attitude, head tracking, human ergonomics, or any other application requiring precise, high-speed, 3D and 6D measurement of moving targets. Phone: (519) 884-5142.

Northern Digital, Inc.

For More Information Circle Action No. 336

VME FOR EVERYONE

PEP's free 44-page four color catalog delivers razor-sharp graphics illustrating our comprehensive line of 3U VMEbus and busless CPU, I/O, mezzanine and piggyback boards, and systems. Also included are PEP's Profibus offerings and a section describing Autobahn and 3U/32 VME. Phone: (412) 921-3322; Fax: (412) 921-3356.

PEP Modular Computers®, Inc.

For More Information Circle Action No. 337

COMPUTER CONTROLLED VALVES

Brochure describes company's line of on-off, Metering and Servo Valves, Pressure Generators, Automated Pressure and flow control systems, Pressure Gage Calibration systems and capability for custom configurations. Address is Cornell University Research Park, Bldg. 4, 83 Brown Rd., Ithaca, NY 14850-1298.

Advanced Pressure Products

For More Information Circle Action No. 338

STACKING FRAMES

Call 800-225-1855 or send for literature on highly versatile stacking units for file servers, printers, controllers and other equipment. Organize your equipment. Save valuable floor space. Variety of useful options available. Product in stock for immediate shipment.

Data Connections, Inc.

For More Information Circle Action No. 339

COLOR LINE SCAN CAMERA

Dalsa's CL-G1 CCD Color Line Scan Camera provides continuous resolution for all colors across the entire scanning region. High resolution of 3x2098 PELs (2098 PELs of each color) per line is provided as 24 bit digital output at a 4 kHz line rate. The CL-G1 is designed for applications such as color document scanning, inspection, color grading, graphic arts, textiles and photographic reproduction. Phone: (519) 886-6000.

Dalsa CCD Image Sensors, Inc.

For More Information Circle Action No. 340

MACHINE/ PROCESS CONTROLLERS

ANAFAZE CLS™ are versatile, inexpensive, 4, 8 and 16 multi-loop PID controllers to run small processes, experiments, machines. Key features: Autotune (Instant Setup); Accepts Most Sensor Inputs Types (even Infrared); 50 Digital I/O for Alarms, Events, Triggers; Computer I/O/Network features. Optional PC-software. Ideal for hundreds of process and machine control applications! New brochure free! Phone: 408-479-0415; Fax: 408-479-0526.

Anafaze Measurement & Control

For More Information Circle Action No. 341

CUSTOM LCD DISPLAYS AND MODULES

DCI's catalog covers the complete line of standard, custom and semi-custom LCD displays. A semi-custom display allows the user to specify custom annunciators on a standard display and reduces set-up costs. Also detailed are DCI's capabilities for miniaturizing and assembly of complete LCD modules. In Olathe, KS—Phone: 913-782-5672; Fax: 913-782-5766.

DCI, Inc.

For More Information Circle Action No. 342

FIBER OPTIC ROTARY JOINTS

Fiber optic rotary joints connect stationary cables to rotating machinery while maintaining all the benefits of fiber end-to-end. They are easily integrated with electrical slip rings and fluid rotary unions in one rugged assembly. For more information write to 40 Thornhill Drive, Unit 7, Dartmouth, Nova Scotia, Canada, B3B 1S1. Phone: 902-468-2263; Fax: 902-468-2249.

Focal Technologies, Inc.

For More Information Circle Action No. 343

ENGINEERING ANALYSIS SOFTWARE

Xmath is a mathematical analysis and graphics environment for X Window workstations. Engineering applications include control systems design, test data analysis, and signal processing. Xmath combines numerical algorithms, interactive 2-D & 3-D graphics, and a programmable Graphical User Interface (GUI). Custom modules available. Phone: 800-932-MATH; Fax: 408-980-0400, or demo Xmath on SunSoft's CDWarc Vol. 4.

Integrated Systems, Inc.

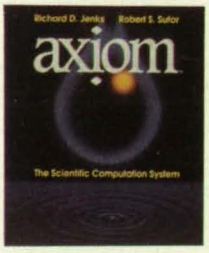
For More Information Circle Action No. 344

INTERFERENCE FILTERS AND CERAMIC CAPACITORS

The Sierra Division of Maxwell Laboratories offers a brochure describing high-reliability EMI filter products along with ceramic cased and discoidal capacitors. Maxwell Sierra builds quality products, delivered on schedule at competitive prices for space, medical, communications, geophysical, military and aerospace customers. Phone: 702-887-5700; Fax: 702-887-5757.

Maxwell Laboratories, Inc.

For More Information Circle Action No. 345



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AXIOM is the latest generation, UNIX based computational software. Powerful symbolic and visual mathematics including hypertext documentation which can be click activated/edited for use as templates in your own work. Explore the worlds of fractal geometry, orbital mechanics, knot theory, quantum mechanics, and other computational disciplines easily—with Axiom.

Numerical Algorithms Group, Inc.

For More Information Circle Action No. 346

LARGE CAPACITY COATING CHAMBER

Thin Film Technology's new vacuum-coating brochure highlights an 8-foot diameter, 14-foot deep coating chamber, with multiple deposition sources and rate/thickness monitoring. Tooling is available for quick adaptability to large parts. Ideal for aerospace applications.

Thin Film Technology

For More Information Circle Action No. 347

CHIP REPLACEMENTS

The Make-it 386 and Make-it 486 are direct chip replacements for the 286 processor providing compatibility with 386 specific software; all in a miniature design. Because both upgrade chips only replace the old processor, your original hardware investment is preserved. The Make-it 486 provides an additional performance upgrade of up to 300%. Phone: 801-224-6550; Fax: 801-224-0355.

TransEra Corporation

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Structural Research and Analysis Corp.

For More Information Circle Action No. 349

DESIGN & CIRCUIT BOARD MANUFACTURE

Douglas CAD/CAM Professional System for circuit board design on the Macintosh computer includes schematic capture, digital simulation, parts placement, manual and autorouting. Designs can be printed, plotted, or translated to Gerber or Excellon files. Manufacturing and photoplotting also available directly.

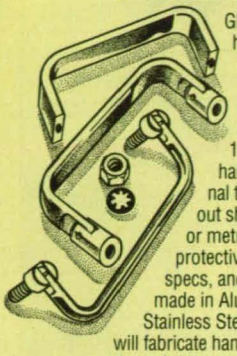
Douglas Electronics

For More Information Circle Action No. 350

Subject Index

(Continued on page 104)

HI-TECH HANDLES



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For More Information Circle No. 651

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For More Information Circle No. 458

Real-Time Network

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Systran Corp., 4126 Linden Avenue, Dayton, OH 45432-3068 USA.
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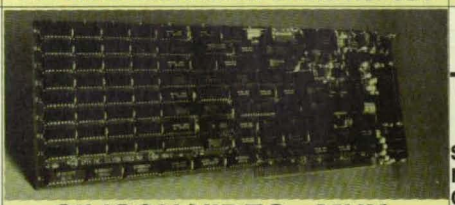
For More Information Circle No. 432



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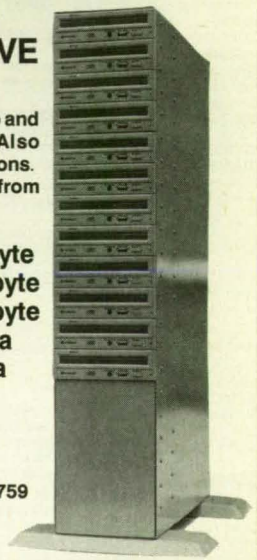

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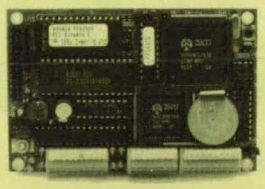
For More Information Circle No. 674

NEW! Little PLC™ $195



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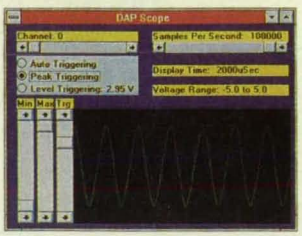
For More Information Circle No. 439

INTELLIGENT DATA ACQUISITION



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For More Information Circle No. 382

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For More Information Circle No. 414

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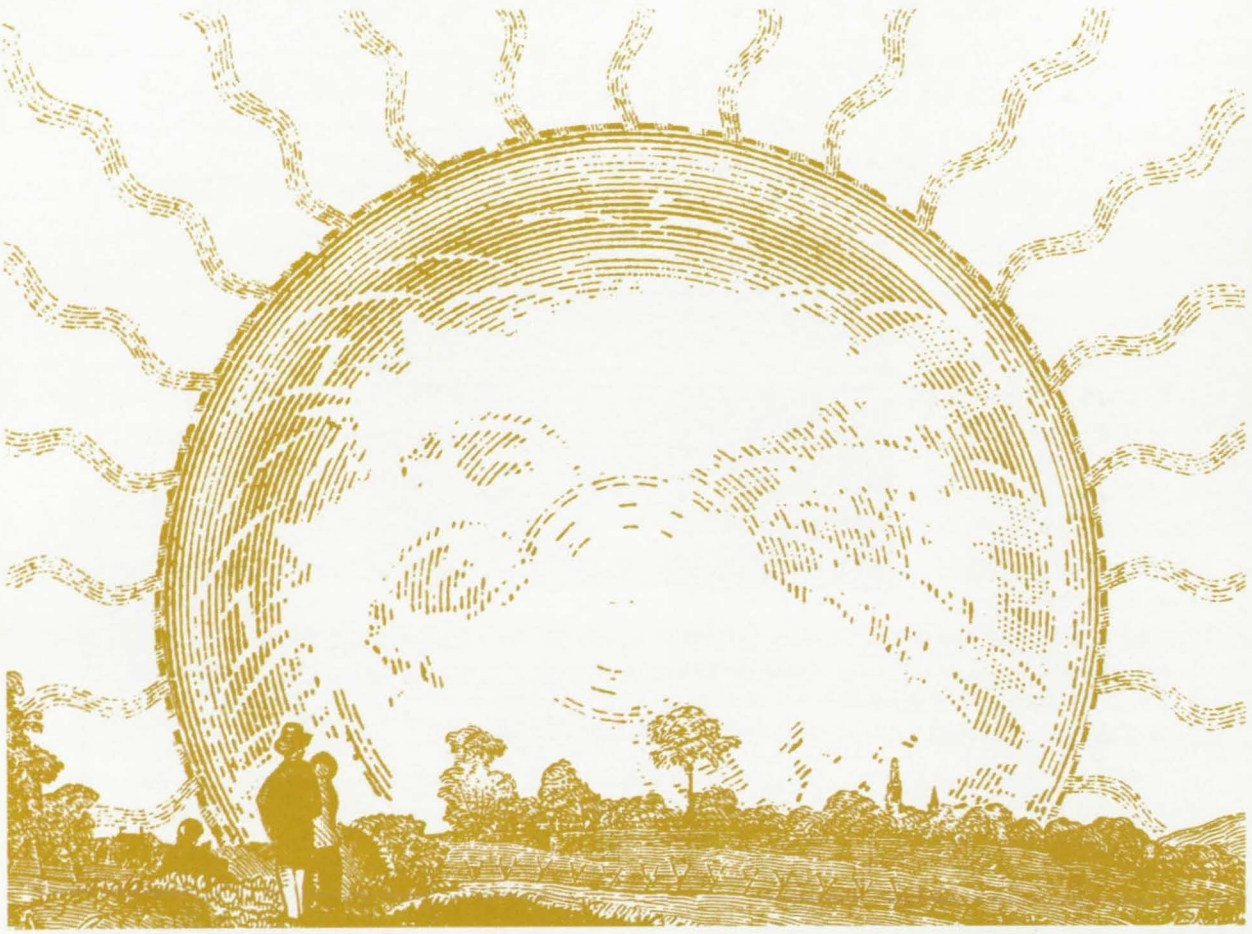

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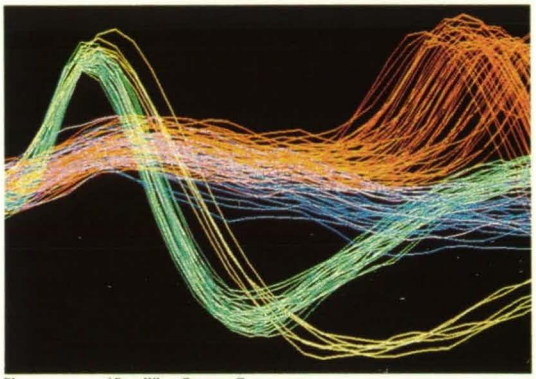

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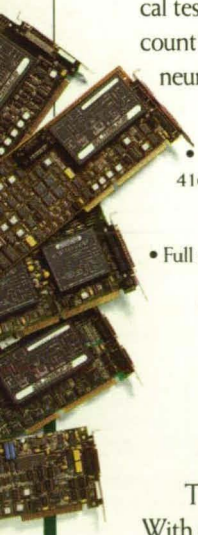

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